Laboratory Investigations i

EARTH SCIENCE

TEACHER'S EDITIO

Laboratory Investigations in
EARTH SCIENCE

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TEACHER'S EDITION

Laboratory Investigations in EARTH SCIENCE

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Laboratory Investigation

INVESTIGATION 1-1—

The primary reason why scientists everywhere have adopted the metric system is that it is easy to use. It is a very logical system because of its decimal parts and because distance, capacity, and mass are simply interrelated. The theoretical basis for the system is this: 1 meter equals 1/10,000,000 of the pole-equator arc through Paris; 1 liter is a cube 0.1 meter on a side; 1 gram is the mass of a cube of water 0.01 meter on a side, at 4°C. The actual measurements are very close to the theoretical. The greatest difference is in the relationship between the standard meter and the pole-equator arc through Paris.

This investigation is intended to show students the time-saving value of the metric system. At their level of maturity, this will be more important than the neat interrelationship of the units.

Measurement

Aim: To compare the English system of measurement with the metric system and to determine the relative ease of using each system

Any plastic ruler with both metric and English graduations will suffice. Metersticks would be clumsy to use. The cards can be cut from old file folders, pad backs, or any stiff paper. Be sure that you do not cut them to an exact inch in either dimension. Try to cut the cards so that their shape is as nearly rectangular as possible, and so that they measure about 4″ x 6″. If all cards are trimmed to the same size, it will be easier for you to check the students' work. Any timepiece, such as a wristwatch, a wall clock, or an alarm clock, is satisfactory.

MATERIALS
Metric ruler
English unit ruler
Stiff paper cards
Watch

Step A Using the English unit ruler, make the following measurements. Be accurate to the nearest 1/16 inch and time yourself.

TABLES OF LINEAR MEASUREMENT

English system	Metric system
1 foot (ft) = 12 inches (in)	1 centimeter (cm) = 10 millimeters (mm)
1 yard (yd) = 3 feet	
1 mile (mi) = 5,280 feet	1 meter (m) = 100 centimeters
	1 kilometer (km) = 1,000 meters

Timing to the nearest minute is satisfactory.

Some of your students may want to convert the sixteenths to decimals for ease of handling. The answer expressed as a fraction should be in 256ths of a square inch. If you need to help the student with the multiplication of fractions, the easiest method is to convert each dimension to sixteenths. Then multiply the number of sixteenths in each dimension and divide the product by 256 (16 x 16).

1. Record the time at the beginning of Step A.

   __________hr __________min

2. Measure the length of the card. __________in

3. Measure the width of the card. __________in

4. Calculate the area of the card. __________in^2

5. Record the time at the end of Step A.

   __________hr __________min

6. How long did it take you to do Step A?

   __________min

The area of the card is simply the product of the two dimensions, which are in millimeters. For most students the difference in the amount of time consumed will be several minutes. The answer to B-13 should be B, and the answer to B-14 should emphasize that the manipulation of fractions is time-consuming.

Step B Repeat Step A, using the metric ruler. Be accurate to the nearest millimeter.

7. Record the time at the beginning of Step B.

_______________hr _______________min

8. What is the length of the card? _______________mm

9. What is the width of the card? _______________mm

10. What is the area of the card? _______________mm^2

11. Record the time at the end of Step B.

_______________hr _______________min

12. How long did it take to do Step B? _______________min

13. Which step, A or B, did you complete more rapidly?

Step_______________

14. Why did the work in that step take less time?

____

____

____

In any discussion of this step, it should be emphasized that conversion within the metric system is no more than moving the decimal point the proper number of places in the correct direction. This is the same as the process of dividing (or multiplying) that is used when working with the English system.

Step C Changing from one unit to another is more cumbersome in the English system than in the metric system. Prove this to yourself by converting the area of the card to the fraction (or decimal) of a square foot and also the fraction (or decimal) of a square meter.

15. What was the area of the card in square inches (A-4)?

_______________in^2

16. How many square inches are there in a square foot?

_____144_____in^2

17. Divide the area of the card in square inches by the area of a square foot in square inches, and you will have the area in square feet. What is it?

_______________ft^2

18. What is the area of the card in square millimeters?

____________ mm^2

19. How many millimeters are there in a meter?

1,000 mm

20. How many square millimeters are there in a square meter?

1,000,000 mm^2

21. Divide the area of the card in square millimeters by the area of a square meter in square millimeters and you will have the area in square meters. What is it?

____________ m^2

Move the decimal place 6 places to the left; this accomplishes division by 1,000,000.

22. Which was the easier calculation, C-17 or C-21?

C-21

23. Why was this so?

It is easier to move a decimal point than to carry out long division.

24. What is one good reason why scientists use the metric system?

Calculations are much easier and less prone to error.

Step D You have been using the English system of linear measurement all your life. Therefore, you are familiar with measurements in inches, feet, and miles. Because of this we have included that system in the textbook. However, you should have some idea about the relationship between English and metric distances. Officially, 1 meter is the same as 3.280833 feet. In converting meters to feet and feet to meters, little error will occur if you use the conversion 1 meter = 3.28 feet.

25. How many inches are there in a meter?

39.37 in

The conversions called for are those that will be most useful to recognize in linear measurements. A set of homework exercises should be designed on the basis of the table at the end of the investigation. The metric system uses the liter for measurements of all fluids, both liquids and gases. However, simple volume measures also are used for fluids. For example, meteorologists use cubic meters rather than liters when discussing certain physical properties of air. On the other hand, the chemist uses liters when he works with gases. Rapid transfer from capacity to volume

is relatively simple, there being theoretically 1,000 liters to a cubic meter. For very precise work, the conversion is 1 l = 1,000.027 cm^3. This is because the standard liter is imperceptibly larger than a cube 10 cm (0.1 m) on a side.

You will notice that we have used the unit "kilogram-weight" in the equivalent of a pound. This is a way to get around the fundamental difference between the pound, which is a force, and the kilogram, which is a measure of mass.

26. How many centimeters are there in an inch?

2.54 cm

27. How many meters are there in a kilometer?

1,000 m

This is 3.28 x 1,000 or, more precisely, 3,280.833 ft. 3,281 ft is highly acceptable.

28. How many feet are there in a kilometer?

3,280 ft

29. How many feet are there in a mile?

5,280 ft

Actually 0.62137 mi

30. What decimal part of a mile is 1 kilometer?

0.62 mi

5/8 mi is 19.084 ft longer than 1 km.

31. What simple fraction is nearest to this part of a mile?

5/8 mi; this is 0.62500 mi.

Here are some handy tables of equivalents in the English and metric systems. There is no need to memorize these tables if you can remember where to find them when you need them.

ENGLISH SYSTEM TO METRIC SYSTEM	
Area	1 in^2 = 6.452 cm^2
	1 ft^2 = 0.09290 m^2
Capacity (fluids)	1 qt = 0.94633 l
Volume	1 in^3 = 16.3872 cm^3
	1 ft^3 = 0.2832 m^3
Weight	1 lb = 0.45359 kg-wt

METRIC SYSTEM TO ENGLISH SYSTEM	
Area	1 cm^2 = 0.1550 in^2
	1 m^2 = 10.764 ft^2
Capacity (fluids)	1 l = 1.0567 qt
Volume	1 cm^3 = 0.0610 in^3
	1 m^3 = 35.314 ft^3
Weight	1 kg = 2.2046 lb

INVESTIGATION 2-1

Orbiting Masses

Centripetal force holds an orbiting mass in orbit. This is equivalent to the gravitational force between a heavenly body and a satellite orbiting around it. In this investigation the earth's gravity is used to supply the centripetal force through the thread to which the orbiting and hanging weights are attached. A neat balance between centripetal force and the tangential force of the orbiting object holds the object in orbit. It is this balance of forces that sometimes is referred to as centrifugal force.

Aim: To discover the relationship between radius and velocity in an orbit

Central Scientific Company makes the equivalent of the apparatus shown. The stock number is 72700-300. The short piece of glass tubing must be fire-filed at each end to prevent a sharp edge from cutting the thread or fishline. The glass tube of a medicine dropper is an excellent replacement for the fire-filed glass tube. The glass should be wrapped with masking tape to prevent it from slipping in the fingers.

Thick, ½-inch washers can be used in place of the ⅜-inch hexagonal nuts. Heavy linen thread, such as shoemakers' thread or carpetmakers' thread, can be used instead of fishline. Plastic rulers with a metric scale along one edge can be substituted for the metersticks.

MATERIALS
¼-inch glass tubing, fire-filed (6″ long)
Nylon fishline, about 14-pound strength (48″ long)
⅜-inch hexagonal nuts (8)
Meterstick
Stopwatch or watch with second hand

Step A Assemble the apparatus as shown in Figure 1:

(1) Thread the line through the piece of glass tubing. (2) Tie 1 mass (nut) to one end of the line; be sure that the knot is secure. (3) Tie 7 masses (nuts) to the other end of the line; be sure that the knot is secure.

To test the apparatus, stand well away from your nearest neighbor. Hold the glass tube vertically in one hand so that the end of the line with 1 mass attached is uppermost. Now, with a slight rotary motion of the hand holding the tube, get the mass into orbit.

Be sure that the knots holding the weights to the line are firmly tied. Be sure that the teams are so placed that no one will be hit by the flying weights.

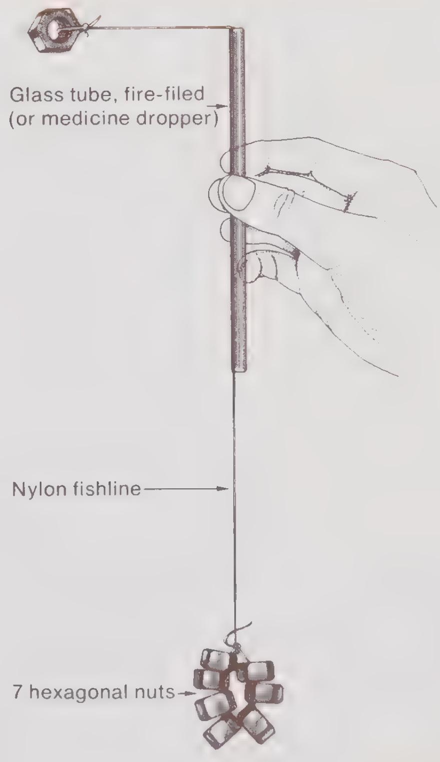

Figure 1

1. As the mass goes into orbit, what happens to the radius of the orbit as represented by the length of line between the mass and the glass tube?

The radius of the orbit increases as the small mass attains its optimum speed in orbit.

2. What happens to the position of the masses hanging below the glass tube?

As the radius of the orbit increases, the large mass hanging below the glass tube rises.

3. What force is holding the single mass in orbit?

Centripetal force

4. What weight is equivalent to that force?

In this experiment, the weight of the hanging mass is equivalent to the centripetal force.

5. What causes the weight?

The weight is the effect of gravity on the hanging mass.

Step B Repeat the experiment three times, producing orbits that differ in radius.

6. As you changed the radius of the orbit, did you alter the force holding the mass in orbit? Explain your answer.

No. There was no change in the amount of mass hanging and there was no change in gravity; therefore, there was no change in force.

7. As you changed the radius of the orbit, what happened to the velocity of the mass in orbit?

As the radius increased, the velocity of the orbiting mass decreased.

Step C Design and carry out an experiment to measure the velocity of the mass in orbit. Perform this experiment with two different radii. To arrive at a good estimate of velocity, time 10 orbits with a stopwatch. Using these results and the radius of the orbit, you can establish a method for estimating the velocity along the orbit in cm/sec.

The difficulty with this step is to estimate the true radius of the orbit. The flying mass will not move in a plane that intersects the tip of the glass tube. The fishline will describe a cone with the tip of the tube at the apex. Let the students discover this, if possible. Let them find a way to approximate the radius of the base of that cone. The answers to **C-8** and **C-9** will vary from student to student and from trial to trial.

8. What were the radius and the velocity involved in the first set of measurements?

Radius ____________cm

Velocity ____________cm

9. What were the radius and the velocity involved in the second set of measurements?

Radius ____________cm

Velocity ____________cm

10. Did this step confirm what you had estimated in **B-7**?

Yes; the greater the radius, the slower the velocity along it.

Step D The force that holds a mass in orbit can be calculated from the equation $f = \frac{mv^2}{r}$.

This step and the next should be omitted with classes that are slow or poor in mathematics.

11. In the experiments you performed in Step C, what changes occurred in f?

None

12. In the same experiments, what changes occurred in m?

None

13. What happened to v as r increased?

v decreased

In the investigation performed, the force (f) and the mass (m) for each investigator remained constant. Therefore, the only variables were velocity (v) and radius (r). Since $f = \frac{m\,v^2}{r}$, and f and m are constant, the fraction $\frac{v^2}{r}$ must be constant. (This is not true for

Step E In Step D you demonstrated that for any specific orbiting body, $\frac{v^2}{r}$ is a constant.

every orbiting situation. For any pair of bodies, the earth and the moon for example, as r increases, f must decrease.)

The numbers arrived at in **E-14** will differ from investigation to investigation. Trials 1 and 2 will not be the same. In fact, there usually are large differences in these numbers even when adept scientists perform the investigations.

14. What values for $\frac{v^2}{r}$ did you find in your two experiments in Step C?

Trial 1 __________ cm/sec^2

Trial 2 __________ cm/sec^2

15. Theoretically, the values in 1 and 2 should be equal. Why are they not equal?

The numbers are not equal because of experimental errors, caused by the problems of (a) maintaining a constant orbit, (b) maintaining a constant velocity, and (c) accurately measuring the radius of the orbit.

16. How could you change the way you performed the experiment in order to reduce the experimental error?

(Any method proposed to improve the accuracy of the experiment must solve the problems posed by the three areas of error noted in E-15. Allow any students who propose feasible improved methods to repeat the experiment.)

A verbal description of why apparent retrograde motion occurs is not wholly satisfactory to most ninth-grade students. This investigation is designed to allow a student to demonstrate for himself that retrograde motion appears to take place but is really a geometric illusion. The investigation is a very good test of the neatness and precision with which a particular student works. Unless both qualities are present, the chances are very good that the answers to questions **B-5**, **B-6**, and **B-8** will be in error by a position number.

Apparent Retrograde Motion

Aim: To demonstrate the cause of apparent retrograde motion

MATERIALS
Hard pencil Straightedge or ruler

The ideal combination of drawing instruments is a well-sharpened 3H pencil and a steel straightedge. Generally, a new plastic ruler with a drawing edge that has not been nicked will serve for the straightedge. Old and battered plastic rulers usually are nicked and warped. They should not be used. You can make a satisfactory straightedge for one-time-only use by cutting 1″ wide strips of stiff cardboard with a good paper cutter. Such strips must be at least 12″ long. A photographic trimming board is a good instrument to use for cutting these strips. If you have a friend who operates a printing shop, have him cut some strips from scrap card stock. Do not use a chipboard; it is too soft.

Step A In this exercise you will test the hypothesis which states that the apparent retrograde motion of a planet is caused by the earth's overtaking and passing the planet as the two revolve around the sun in different orbits.

Figure 1 has been drawn to scale with one exception: The background of stars against which we observe the motion of planets should have been drawn hundreds of feet beyond where it is placed at the top of the page. The orbits of Earth and Mars are represented by arcs at the bottom of the page. In the scale to which they are drawn, ¼ inch is equivalent to 10 million miles.

Look at the data in the following table.

ITEM	Earth	Mars
Radius of orbit, in million miles	94	142
Period of revolution, in earth days	365	687
Circumference of orbit, in million miles	295	445

1. Using this data, calculate in inches the radii of the orbits shown in Figure 1. Make the calculations to the scale noted above (¼ inch = 10 million miles).

Earth $9.4 \times \frac{1}{4} = 2.35$ in

Mars $14.2 \times \frac{1}{4} = 3.55$ in

2. Calculate the distance along their orbit that Earth and Mars each travel in one earth day.

Earth $295 \div 365 = 0.808$ million mi

0.8 and 0.81 are acceptable answers.

Mars $445 \div 687 = 0.647$ million mi

0.65 is an acceptable answer.

3. Explain why one of the planets travels slower than the other.

The planet that is farther away from the sun is influenced less by the gravitational pull from the sun; therefore, it travels slower than the planet that is nearer the sun. In addition, if the nearer planet were not traveling at a sufficiently fast speed, it would be pulled into the sun.

Both planets are revolving around th sun. According to Newton's laws o gravity, the farther a planet is from th sun, the less is the sun's gravitation pull on it. Therefore, if a distant plan did not move slowly in its orbit, it woul fly off into space.

Note

A student may call upon Kepler's sec ond law of planetary motion or upo his third law to answer this questio See the answer to Review Question 6 the end of Chapter 3 in *Earth Scienc*

4. In Figure 1, the distance between the equally spaced marks on the orbits for Earth are 0.25 inch apart. The marks on the Mars orbit represent the same passages of time. Using the data you found in **A-2**, calculate the distance from one mark to the other on the diagram of the Mars orbit.

$$0.808 \div 0.25 = 0.647 \div \times$$
$$0.808 \times = 0.25 \times 0.647$$
$$\times = 0.16175/0.808$$
$$\times = 0.200$$

Approximately 0.200 in

Step B Use a well-sharpened 3H pencil and a good straightedge or ruler for this work. Place the straightedge as accurately as you can to draw a line through the marks labeled 1 on the orbits of Earth and Mars. Draw this line to the lowest of the three closely spaced lines at the top of the page. Label the point of intersection 1. Repeat this operation with the points marked 2. The mark for point 2 on the lines at the top of the page lies to the left of the mark for point 1. Any apparent motion in this direction we will call *prograde motion*.

Continue to align your straightedge on points with the same number along the orbits of Earth and Mars. Instead of drawing lines, put a point on the lowest line at the top of

Neatness and precision are importar here. The lines must be straight an must pass directly through the pair of marks.

the page. As soon as the point you have just made lies to the *right* of the last one you made, apparent retrograde motion has begun. Place all points for retrograde motion on the middle line of the three lines at the top of the page.

Continue plotting the retrograde motion on the middle line until it reverses and becomes prograde again. Be sure to number the points you make at the top of the page.

5. At what point did you last plot prograde motion before retrograde motion began?

Point 7

6. At what point did retrograde motion cease?

Point 12

7. Why is *apparent* retrograde motion the proper name for the observed motion of Mars?

It is called apparent retrograde motion because Mars does not actually change the direction of its motion in its orbit around the sun. Mars only appears to change its motion to an observer on Earth.

Acceptable answers are 62, 61.8, and 61.80.

8. It takes 12.36 days for Earth to move from one point to the next in its orbit, as shown in Figure 1. For approximately how many days is Mars in apparent retrograde motion?

The distance between points represents 10 million miles. Therefore, $10 \div 0.808 = 12.36$ days. Retrograde motion in Figure 1 takes place over 5 spaces; therefore, $12.36 \times 5 = 61.80$ days.

Approximately 61.80 days

The determination of density is a relatively simple procedure for objects denser than water. This investigation and the next are a pair that should be performed one after the other, provided there is time. The first of these produces an approximation that will be in error by as much as 20%, depending upon the accuracy and graduation of the spring scale and the graduated cylinder.

INVESTIGATION 3-2

Density of a Solid

Aim: To determine the density of a solid

Definition: Density is the mass of a unit volume of a substance. Density of a solid is usually stated as the mass, in grams, of an amount that is 1 cm^3 in volume.

MATERIALS
Balance and weights, or spring scale
Graduated cylinder
Beaker of water
Thread
Piece of stone

The balance and weights should be of good quality. A Harvard trip balance and weights, or an Ohaus triple beam balance, are ideal. The recommended spring scale is one graduated in grams. We have found that those supplied today, even by old and established firms, often are quite inaccurate. The most common fault is that the indicator does not register zero when the spring is at rest. When this is so, the students should be instructed to apply the needed adjustment to the weight read on the scale.
The best-size graduated cylinder is 100 ml. This restricts the size of the object to be submerged, but the cylinder is graduated in milliliters.
If beakers are not available, paper cups will do.
Any kind of cotton thread is satisfactory.
The sample objects may be any small pebbles or pieces of stone. The crushed stone used for paving walks is quite satisfactory. If all the students use the same kind, your work will be lightened, since you only need to do one determination. The density will usually be between 2.2 and 2.8 g/cm^3.

Step A To determine the density of a solid, divide its mass in grams by its volume in cubic centimeters. Examine your sample to see how this may be done.

1. How can you estimate the mass of your sample?

By using a spring scale or a balance

2. Determine the mass of your sample.

(Answers will vary.)

If a spring scale is used, it should be read to 0.5 g. If a balance is used, it should be read to 0.1 g on a trip balance, or 0.01 on an Ohaus triple beam.

3. How do you determine the volume of an object such as a box?

By measuring the three dimensions and finding their product in cubic units.

4. Can you apply this method to your sample?

The method cannot be used for the object except to set a limit.

5. Why?

The object is irregular in shape.

The idea that the volume of an object that is irregular in shape can be estimated by measuring the volume of water it displaces seems obvious to an adult. It may not be so obvious to some of the students. This particular submersion method is the least complicated to perform. It also is the least accurate. The graduation of the cylinder prevents determination of the volume with any better accuracy than about 0.5 ml (cm^3). If a cylinder larger than 100 ml in capacity is used, the estimate will be less accurate. A submersion method is used by mineralogists for determining volume and mass of extremely small particles. This employs a specially designed vessel called a picnometer. Its use requires such skilled technique that it is not practical for a classroom experiment. If a picnometer is available in the physics laboratory, you might practice the technique and demonstrate it to the class.

Step B In this step you will learn how to determine the volume of an object that is irregular in shape. Look at the apparatus that you have.

6. Is there any piece of apparatus that can be used to measure volume? If there is, what is it?

Yes; the graduated cylinder

7. How would you use this to estimate the volume of the object?

Partly fill the graduated cylinder with water and record the volume. Submerge the object in the water and record the combined volume of the water and the object in the cylinder.

If you subtract the initial volume of water from the volume with the submerged stone, you will have an estimate of the volume of the object.

8. Carry out the method you described in **B-7**. What is the volume of the water alone?

________ ml

What is the volume of the water plus the object?

________ ml

What is the volume of the object?

________ ml

9. What is the volume of 1 ml? 1 cm^3

The volume of the object in cm^3 is the same number as its capacity measure in ml.

10. What is the volume of the object in cm^3?

________ cm^3

The density of an object is its mass per unit of volume: $d = \frac{m}{V}$. Scientists universally use g/cm^3 as a statement of density for solids and liquids. The mass of the object was established in **A-2** and the volume to be used was determined in **B-10**.

Step C From the data that you have accumulated, make a first approximation of the density of the sample object.

11. What is the mass (**A-2**)? ________________g

What is the volume (**B-10**)? ________________cm^3

What is the density? ________________g/cm^3

The method used in this experiment should yield a density of from 2 to [illegible] g/cm^3 for a piece of stone.

12. How accurately did you measure the mass of the sample object: to the nearest g, to the nearest 0.1 g, or to the nearest 0.01 g?

To the nearest ________________g

The accuracy of the measurement of the mass is the smallest unit of calibration on the balance, or spring scale, used.

13. How accurately did you measure the volume of the sample object: to the nearest ml, to the nearest 5 ml, or to the nearest 0.5 ml?

To the nearest ________________ml

The volume of the object can be measured only to the accuracy of the smallest unit of calibration on the cylinder.

14. Why was your first approximation of the density not an accurate estimate?

Errors in measurement were too large.

____

If a balance has been used, the greatest error is in the measure of volume. If a spring scale has been used, both measures are equally inaccurate.

To make an accurate estimate of the density of the object, you will have to do another investigation. In the next investigation you will use a method suggested by an ancient Greek philosopher, Archimedes. The principle that he discovered is essentially this: An object submerged in water is buoyed up by a force that is equal to the mass of the fluid the object displaces.

This investigation is a continuation of Investigation 3-2. It may be used alone or following that investigation. It may be used as a demonstration or be assigned to selected students. The method used here is the one generally used to determine the density of solids heavier than water. We have included some Socratic teaching in this investigation and hope that most of the students in your class can reason the answers properly. However, you may have to help some of them.

Archimedes Principle

Aim: To determine the density of an object by using Archimedes' principle

MATERIALS
Balance and weights
Beaker of water
Cork
Thread
Piece of stone

The teacher's notes concerning the balance for Laboratory Investigation 3-2 apply here. If that investigation has been done, each student should use the same piece of stone he used in 3-2. This will allow him to make a comparison of the accuracy of the two methods. The only added material is a cork. A small piece of wood may be used in place of this.

Step A If you have not done so, read the paragraph at the end of Investigation 3-2. Then assemble the apparatus as shown in Figure 1 and place the cork in the beaker of water.

The purpose of this step is to make the student aware of the two forces that are acting upon an object in water.

1. In what direction does the force of gravity pull an object?

   Downward

2. When we weigh an object, what are we really measuring?

   The force of gravity acting upon the object

3. When you hold a cork under water and then let it go, what happens?

   The cork rises to the surface.

4. What force causes this to happen?

   The buoyancy of the cork in water

5. In what direction does this force act?

   Upward

6. Why does the cork float? Give your answer in terms of forces acting upon the cork.

   The force of buoyancy pushing upward is greater than

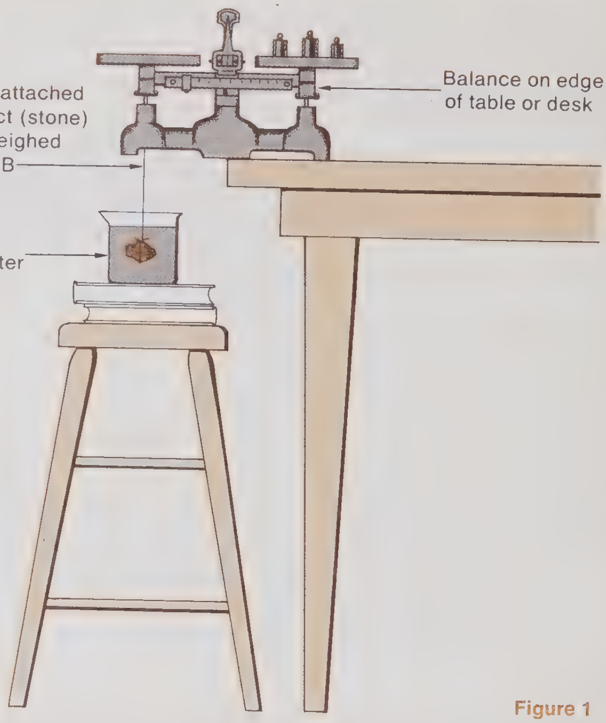

Figure 1

the force of gravity pulling the cork downward in the water.

This is a very important observation and critical to the line of reasoning.

7. Does the cork float on the surface of the water, or is part of the cork submerged in water?

Part is submerged.

8. If the force of gravity were greater than the force of buoyancy, would the cork float, or sink?

It would sink.

The phrasing of this question is critical, especially "floating cork." The floating cork is partly submerged and displaces some water.

9. If the force of buoyancy *acting upon the floating cork* were greater than the force of gravity, what would happen?

The cork would float completely out of water.

10. Does this happen? No

11. Since the cork is floating, the forces of buoyancy and gravity acting upon the cork are *exactly* the same. Under these conditions, does the cork displace any water? Why?

Yes. Since the cork is partly submerged, it displaces some water.

The floating cork is *not* in motion. Both forces are accelerations. Therefore, if either force were greater than the other, the cork would be in motion, either up or down. It may be necessary to explain this point to the students.

12. Recalling Archimedes' principle, what mass of water is displaced by the floating cork?

A mass of water exactly equal to the force of buoyancy, or gravity

Precise phrasing of this answer should not be expected. We have given the most common "correct" answer. A mass cannot be equal to a force. The mass of the water displaced is exactly equal to the value of m in the equation $f = mv^2$. Since the cork is at rest, v disappears from the equation and there is no f, or acceleration. Since both v and f are zero, only m is left.

13. Under the conditions of this experiment, the forces of gravity and buoyancy are exactly equal. The cork no longer has any weight, but its mass is unchanged. How much weight has the cork lost?

An amount of weight exactly equal to the weight of the mass of water it displaced

An equally acceptable answer is that the cork has lost all its weight.

Step B In Step A you came to the conclusion that a mass in water loses an amount of weight that is exactly equal to the mass of water it displaces. Attach one end of a piece of thread to the center of the underside of the left balance pan. Be sure to use the left-hand pan. Attach the object to the other end of the thread. Weigh the object by balancing it with weights placed on the right-hand pan and by using the slide. The apparatus for Steps A and B is shown in Figure 1.

The fact that both mass and weight are involved requires that the two measurements be carefully recognized and labeled. To emphasize this, we have labeled the required answers as either "g-wt" (gram-weight) or "g" (gram). The gram-weight is the result of gravity acting upon 1 g of mass. Great care must be exercised in attaching the thread to the balance pan. If you are using a trip balance, it must be attached to the fulcrum wire or bar connecting the vertical member on the pan and the end of the beam. If you are using an Ohaus balance, it is attached to the pan hook, and the aluminum support supplied with these balances must be placed astraddle the pan without touching it. Do not remove the pan.

14. What total weight balances the weight of the object?

__________ g-wt

This weight should be recorded to the smallest division of the balance scale. Estimation beyond this should not be required.

15. Since you used a balance, gravity acted equally upon the object and the weights. Therefore, the mass of the object

This mass must be exactly the same as the answer in **B-14**.

is the same number of grams as its gram-weight. What is the mass of the object?

______________g

A false reading will result if the suspended object touches either the side or the bottom of the beaker, or if the object is not fully submerged at all times.

Step C Now move a beaker of water under and up on the suspended object so that the object is completely submerged but does not touch the beaker at any place.

This weight should be several g-wt less than the answer in **B-14**.

16. Reweigh the object in water. What does it weigh now?

______________g-wt

17. How much weight has the object lost? (**B-14** minus **C-16**)

______________g-wt

The gram-weight equivalent of the force of buoyancy is the same as the gram-weight noted in **C-17**. Since gram-weight actually is a force, the two are equal.

18. The weight was lost because of buoyancy. What was the gram-weight equivalent of the force of buoyancy?

______________g-wt

The same weight as in **C-17** and **C-18**. This may seem to be useless repetition. It is done to reinforce the relationships between loss of weight, buoyancy, and weight of water displaced. Each is a distinctive factor and each carries the same number. In each case, the number has a different meaning.

19. What gram-weight of water is displaced?

______________g-wt

20. We can consider that 1 g-wt of water has a mass of 1 g. What was the mass of the water displaced?

The same mass as in **C-17** ______________g

The same volume as in **C-17**

21. What volume is occupied by the mass of water displaced?

______________cm^3

The volume will depend upon the kind of material of which the object is composed.

22. The water was displaced by the object. What is the volume of the object?

______________cm^3

If the students have performed Investigation 3-2 and used the same object in the two investigations, have them compare the results and discuss the relative accuracies of the determinations. Emphasize that the accuracy of observation controls the accuracy of the result.

Step D To compute the density of the object, remember that $d = \frac{m}{v}$.

23. What is the mass of the object (**B-15**)

______________g

What is the volume of the object (**C-22**)

______________cm^3

What is the density of the object? ______________g/cm^3

This investigation is included to give the more able students an interesting problem to solve. It may follow Investigation 3-3, or it may be deferred until Chapter 24 has been studied. There are two sections to the investigation. Steps A, B, and C are devoted to a first approximation of density by the obvious method of weighing a known volume of the liquid. The remainder of the investigation is devoted to a more precise method that contrasts the buoyant quality of the salt solution with that of pure water. At the end of these notes, there is a suggested project for inquisitive students.

Density of a Liquid

Aim: To determine the density of a liquid in g/cm^3

MATERIALS
Balance and weights
Graduated cylinder
Beaker of fresh water, preferably distilled
Beaker of salt solution
Thread
Piece of material heavier than water
Paper towel

Although tap water is satisfactory as a standard for this investigation, a truly precise measurement can be made with distilled water. The object heavier than water may be a piece of quartz or metal. A 100-g brass weight is excellent, but it must be wiped absolutely dry before being put away. Whatever is used, it must be impervious to water.

Step A The most obvious way to determine the density of a liquid is to weigh a carefully measured volume and then divide the mass (in grams) by the volume (in cm^3).

1. Carefully weigh an empty, dry graduated cylinder. What is the weight to the nearest 0.1 g?

_______________g-wt

The only precaution necessary is that the graduated cylinder be dry. There is no need to go through the chemist's elaborate procedure of drying with alcohol and acetone. Paper towels and facial tissue will produce a sufficiently dry cylinder.

Step B Pour enough salt water into the cylinder to fill it nearly to the top of the graduations.

2. Read the volume of the salt water you have poured into the cylinder. Read the *bottom* of the curved surface of the liquid. What is the volume to the nearest 0.5 ml?

_______________ml

3. Weigh the cylinder and the solution it contains. What is the weight to the nearest 0.1 g?

_______________g-wt

The more salt solution used, the less important the experimental error in its weight. Thus, be sure that from 90 to 99 ml are used. The denser the salt solution, the more noticeable the differences will be. For this reason, we recommend between 25 and 30 grams of table salt per 100 ml of solution. Some instruction about how to read the volume of a fluid in a graduated cylinder may be necessary. Read the bottom of the meniscus, the curved surface of the water. Make sure the meniscus is at eye level; otherwise, there will be a slight parallax error.

Step C You now have enough data to make a first approximation of the density of the salt water.

4. From the data you accumulated in Steps A and B, determine the weight of the solution by making the calculations indicated below:

Weight of cylinder and solution (**B-3**) _______________g-wt

Weight of cylinder (**A-1**) _______________g-wt

The answers to the questions will vary, except for **C-7** and, hopefully, **C-8**.

Weight of solution ____________g-wt

5. What is the mass of the solution? ____________g

6. What is the volume of the solution (**B-2**)?

____________cm^3

7. What equation is used for determining density?

$d = m/v$, when the measurements are in grams and cm^3

Careful students should arrive at a density differing by no more than 1% from your determination. Students whose error is as great as 5% should repeat the investigation.

8. What is the density of the solution? ____________g/cm^3

In the method set forth, it is not necessary to determine the volume of the object submerged in the water and its volume in the salt solution because the volume is constant. The volume of the object is the loss of weight in grams in distilled water, expressed as cm^3.

Step D A more accurate way of determining the density of a liquid is to compare the loss in weight of an object weighed in pure or distilled water with its loss when it is weighed in the liquid. To do this, use a procedure similar to that used in Investigation 3-3. Follow the instructions given in Step B of that investigation.

9. What is the weight of the object in air?

____________g-wt

10. What is the weight of the object in pure water?

____________g-wt

11. What is the loss of weight? ____________g-wt

Step E Carefully dry the object. Now weigh it in the salt solution.

12. Why was it necessary to dry the object before weighing it in the salt solution?

To prevent dilution of the salt solution in the immediate vicinity of the object.

13. What is the weight of the object in the salt solution?

__________g-wt

14. What was the loss of weight? __________g-wt

Step F You now have the data necessary to determine the density of the solution by comparing the masses of equal volumes of pure and salt water.

15. Archimedes' principle states that an object submerged in a liquid loses an amount of weight equal to the weight of the liquid displaced. What weight of salt solution was displaced? (Estimate this from **E-14**.)

__________g-wt

16. The object displaced its own volume of both pure water and salt water. Therefore, the weight losses in pure water and salt water apply to identical volumes. From the two weight losses and the knowledge that the density of pure water is 1 g/cm^3, you can calculate the density of the salt solution. The equation for this is:

$$\frac{\text{Weight loss in pure water (a)}}{\text{Weight loss in salt water (c)}} = \frac{\text{Density of pure water (b)}}{\text{Density of salt water (d)}}$$

The values for (a), (b), and (c) are known; only (d) is unknown. You can transform the equation to $(d) = \frac{(b) \times (c)}{(a)}$. Substitute in this equation the experimental values you observed, and do the mathematics to obtain (d), the density of the salt solution. What is its density?

__________g/cm^3

Some teachers may feel that we have given too much away in our questions. This has been done deliberately. We want the student to understand clearly each step of reasoning that is involved. If the students keep notebooks of laboratory work, it should be suggested that in writing up this investigation they compare their final determination of the density of the salt water with the first approximation. They should then be required to explain why these estimates differ.

A good project for a student at this time is to construct a simple hydrometer. This can be made from a 6″ test tube loaded with shot or sand. A strip of printed millimeter-scale paper is cemented *inside* the test tube. The scale should be read for pure water and for two concentrations of salt water of known densities. Then a graph can be constructed for converting scale readings to densities.

This very short investigation can be extended in several ways. These are detailed below.

Evaporation

Aim: To discover what happens when salt water is evaporated

MATERIALS	
Salt	Asbestos mat
Evaporating dish	Beaker
Glass stirring rod	Test tube
Bunsen burner	Cold water
Tripod	

The equipment needed should be available in any high school chemistry or general science laboratory.

Although a porcelain evaporating dish is best, a glass beaker makes an excellent substitute. If a beaker is used, great care must be exercised at the final evaporation of the water and drying of the residue; too much heat may crack the beaker. If neither of these is available, small aluminum-foil cake or tart pans, from 3″ to 4″ in diameter, may be used. They can be found in almost any supermarket.

An alcohol lamp or a hot plate may be used instead of a Bunsen burner.

A ringstand and ring may be substituted for the tripod. These will not be needed if a hot plate is used.

An ordinary drinking glass may be used to provide the cooling surface. If a glass or a beaker is used, a few ice cubes in the water will be helpful. As a last resort, you may use a *waxed* paper cup with water and ice cubes.

As a substitute for a glass stirring rod, you may use wooden tongue depressors, but they impart a "woody" taste to the water. A fire-filed glass tube about 8″ long may be used as a stirring rod if solid rods are not available.

Step A Put ¼ teaspoon of ordinary table salt into an evaporating dish and add ½ test tube of water. Stir with a glass rod.

1. What happens to the salt when it is stirred in fresh water?

   It dissolves.

2. Can you see any salt in the water?

   No. (However, there usually are a few undissolved grains of salt at the bottom.)

3. What happened to the rest of the salt?

   The salt was dispersed throughout the water. The salt molecules and ions mixed with the water molecules and were invisible.

4. Taste the solution by removing a drop with the stirring rod and transferring it to your tongue. Was there any salt in that drop? How do you know?

   Yes. The drop tasted salty.

The students should be cautioned to hold the condenser, or test tube, at an angle and thus avoid hand contact with too much steam.

Step B Place the container of salty water on an asbestos mat on the tripod. Light the Bunsen burner and place it under the tripod, as shown in Figure 1. Bring the water to a boil. Hold a test tube half filled with cold water about 4 inches above the boiling water.

Figure 1

5. What happens to the outer surface of the test tube of cold water?

It becomes covered with water drops, which drip back into the evaporating dish.

6. How did these drops form?

Condensation of water vapor

7. With a freshly rinsed and dried stirring rod, remove a drop of water from the *outer surface* of the test tube. Taste it. What have you learned?

The condensed water is tasteless. The salt has not evaporated but the water has.

Step C Evaporate the salt solution to dryness by continuing to boil off water.

8. Taste the residue in the evaporating dish. How does it taste?

Salty

9. How can fresh water be prepared from salty water?

By distillation, the process of evaporating water and condensing the water vapor

10. River water rarely tastes salty. Ocean water is very salty. How do you suppose the salt accumulated in the ocean?

During the millions of years in which the oceans have developed, many times their volume of water has been evaporated. This water has been deposited on the land, and as it has trickled over the land to the rivers, some salts have dissolved in it. The river water, with a low salt content, has returned to the oceans. Pure water has evaporated from the oceans. As this cycle continues, the oceans become more salty. They now contain about 3.5 g of salts per 100 g of solution.

When the water in the evaporating dish is reduced to about a teaspoonful, the heat should be reduced. If a beaker or aluminum pan is used, the heat should be removed before the residue becomes dry.

Substitute a few crystals of copper sulfate (blue vitriol) for the salt. *Do not let the students taste this solution.* The water condensed from steam produced by boiling this solution is colorless. This demonstrates that only the water has evaporated.

To show that not all substances can be separated from water by distillation, add a few drops of ammonia water (ammonium hydroxide). Test the condensed water with litmus paper (or phenolphthalein solution). The condensed water will give an alkaline reaction. The ammonia in solution boils off with the water. All easily volatile substances, such as hydrochloric acid, alcohol, and acetone, will do this. Ammonia water is the safest and most easily tested of these.

INVESTIGATION 4-1—

The smelting of an ore to produce a metal can be done in the laboratory. Ores that a beginner can smelt easily are galena, an ore of lead, and cuprite or tenorite, oxide ores of copper. Of these, galena is the most easily procured. The black oxide of copper (tenorite) will be found in the chemistry laboratory as "copper oxide, black, wireform." A little of it should be on hand for the students who go through this exercise rapidly and want to reduce some other ore to its metal.

The most difficult part of this experiment is to develop the technique of using the blowpipe. The trick is to blow steadily with not too much force. An expert keeps a steady flame while breathing normally. This is because he has learned how to keep his cheeks inflated with air and during inspiration, how to pump air into his mouth with his tongue. It takes practice. Don't expect the students to achieve perfection in a single session. Some people never learn to use a blowpipe properly.

Producing a Metal from One of Its Ores

Aim: To produce a metal from one of its ores

MATERIALS
Small fragment of galena
Charcoal block
Blowpipe
Bunsen burner

Break up a lump of well-crystallized galena into small fragments. Select those that are about the size of a dried split pea. The smaller fragments should be put aside for **D-14**.

Standard charcoal blocks and blow-pipes may be on hand in the chemistry laboratory. If not, they may be purchased from any good school science supply house.

If Bunsen burners are not available, use alcohol lamps. As a last resort, stubby plumber's candles or the tag ends of household decorative candles may be used.

In addition to the students' materials, you will need an old scalpel to cut or scratch the beads produced in **C-11** to answer the question in **C-12**. Also, you will want a smooth piece of iron to use as an anvil and a light hammer for **D-13–14**.

Step A Galena is an ore of lead. Examine the small piece that you have been given.

1. What is the color of galena? Silvery

2. Is galena dull, or shiny? Shiny

3. The piece of galena that you have was broken from a larger piece. Does galena appear to break irregularly, or in such a way as to produce small, definite flat faces at definite angles to one another?

It breaks to produce definite flat faces at definite angles to one another.

4. What would you estimate the angle between two adjacent faces to be?

90 °

5. In **A-1–4** you discovered the major features by which a mineralogist recognizes galena. How would you describe galena?

It is silvery and shiny, with fractures at right angles.

STEP A—

In this step the students are asked to recognize certain characteristics of galena. Its massiveness cannot be recognized from the small samples.

This step will take varying amounts of time to accomplish. Tell the students to get your approval of their technique before going on to Step C.

Step B Before you do this experiment, you must learn the laboratory technique of using a blowpipe.

6. Light the Bunsen burner and cut off its air supply. This produces a yellow flame. Adjust the gas flow so the flame is not more than 2 inches high.

7. Put the mouthpiece of the blowpipe to your lips. Blow through the instrument, directing the tip to the palm of your hand. Do you feel the air jet? If not, the tip is plugged. If this has happened, ask your teacher to clear the tip for you.

8. When you know that the blowpipe is clear, put the tip in the top part of the Bunsen flame and blow gently. Experiment until you learn how to direct the flame as you want. Experiment to find out how to produce a blue flame and a yellow flame in the form of little jets that you can direct. When you are satisfied that you know how to use the blowpipe, go on to Step C.

Be sure that you have extra bits of galena on hand for those who spill their samples or blow them away.

Step C Galena is a mineral composed of lead and sulfur. You can extract the lead from it by smelting the mineral with carbon. The first step in this process oxidizes, or combines, the sulfur and the lead with oxygen from the air. This is done by heating the mineral in air. The sulfur produces a gas, sulfur dioxide, that escapes. The lead produces lead oxide, a yellowish powder that remains. In the second step the lead oxide reacts with charcoal, which is actually carbon. This step also requires heat. The carbon combines with the oxygen in the lead oxide to produce oxides of carbon and the metal lead. The entire process can be done continuously on a charcoal block.

Ideally, the students themselves should form the pits in the charcoal block. However, if time does not permit, cut the pits beforehand.

9. With the tip of a penknife or a pencil, grind a little pit in the charcoal block near one end. Make the hole about 1/4 inch in diameter and 1/8 inch deep.

The following happens as a result of expansion and because sulfur dioxide is being formed. The material will melt in a short time and form a ball in the pit. The technical name for this ball is bead. It may bubble a little from escaping SO_2 and CO_2. It will appear to be spinning because of a thin film of oxide on the surface that is blown about by the flame jet. The light-colored deposit that forms around the pit during heating is partly lead oxides and partly ash from the charcoal. The lead oxide will be yellowish when it is cool.

10. Place a small piece of galena in the pit you have made in the charcoal block. Grasp the block with one hand, at the end farthest from the pit. Hold the block almost horizontally. With the blowpipe, direct the tip of a blue flame against the piece of galena. Keep the flame there for several minutes. What happens?

11. Continue to flame the galena with the tip of the flame from the blowpipe until the substance in the pit is a glowing little ball of molten material. This little ball is called a bead. Change the flame jet to yellow for a few seconds. Stop blowing and let the block and its contents cool. What is the appearance of the bead?

NO. 11—

The change from a blue to a yellow flame is not imperative. The use of a yellow flame after the blue flame reduces much of the surface film of lead oxide. This is so thin that it merely lightens the surface color of the lead. Most of the blackness is from carbon particles and roughness of the surface.

12. Carefully roll the bead out of the pit and onto a piece of paper. Don't lose it! Ask your teacher to cut the bead for you. Examine the cut surface. What color is it?

A cut surface or scratch on the bead will reveal the true color of the lead, a bluish-gray called lead-gray.

Step D The product of your investigation may simply be melted galena. See whether you have changed a physical property. Take your product to the anvil and gently tap it with a hammer. Then, take a small piece of galena and place it on the anvil. Tap it with a hammer.

This step should be carried out under your supervision. If necessary, question the student until he arrives at the observation that the lead flattens, while the galena shatters. If the reduction has been successful, the little ball of lead will flatten easily when it is tapped. When black copper oxide is used, the change in color is much more dramatic than the change that occurs with galena. It is easier to form a lead bead than a copper bead because lead melts at a much lower temperature than copper. Very often the copper wire retains its true color only during the heating period. As it cools, the surface blackens with a thin film of oxide. The student should be instructed to snap the wire in two and examine the freshly fractured surface. Although copper is highly malleable, the wire is very brittle. The reason for this is twofold: the copper in the reduced wire is crystalline, not annealed, and there is considerable red oxide mixed with it.

13. What happens?

When galena is tapped on an anvil, it shatters.

14. What is one difference between galena and the substance you produced from it?

The heat together with the carbon treatment changed the brittle galena to a malleable substance.

15. What, probably, is the substance you produced?

Lead

INVESTIGATION 5-1—

Recognition of the more common kinds of rocks is necessary for an understanding of the earth sciences. Ideally, this learning should take place in the field, from the rocks en masse. Few schools are so fortunately situated that this is possible. The next best thing is to study fragments of the rocks. The best classroom situation is to have sizeable samples of each kind of rock used for this exercise in addition to the small fragments supplied to the students.

Selection of materials should include characteristic sedimentary, metamorphic, and igneous types. Since there are relatively few areas in the country where it is possible to collect these locally, most schools will find it convenient to purchase classroom material. However, use as much local material as possible.

Characteristics of Common Rocks

Aim: To become familiar with the characteristics of some common types of rocks

MATERIALS
Box of rock samples Hand lens Dilute hydrochloric acid

Step A The first step in any attempt to classify objects is to sort the collection into two or three major categories. This applies to all kinds of classifying.

1. What are the features by which sedimentary rocks may be distinguished from crystalline rocks?

Sedimentary rocks may be recognized by their uniform grain size, the reasonably uniform composition of the grains, and the presence of a cementing material. In crystalline rocks, crystals are usually more readily apparent and are scattered throughout.

2. Which of these features may be used to recognize a fragment of a sedimentary rock?

(This answer should be similar to the answer in A-1. If stratification is mentioned, it should be made secondary, since it is rarely evident in a small fragment.)

The specimens supplied to the students should be as large as they can handle conveniently. Pieces about 2″ x 2″ x 1″ are fine. Pieces as small as 1″ x 1″ x ½″ can be used only if they are highly characteristic. Empty 1-lb coffee cans make good storage containers. Selected material can be purchased from many school-supply companies. The Macalaster Natural Laboratory Kit, Rock Texture Kit, and Rock Composition Kit will be found useful. Individual specimens of rocks and material for classwork may be purchased from several suppliers. The best known are:

Ward's Natural Science Establishment, Inc.
P. O. Box 1712
Rochester, N. Y. 14603

Southwest Scientific Co.
P. O. Box 10
Hamilton, Montana 59840

Very often a local "rock shop" can help you.

For your convenience, each specimen of the same specific type of rock should be given the same identification number. Place a circular spot, ¼″ in diameter, of white matte paint on each sample. Place this where it will not obscure characteristic features. When the paint is thoroughly dry, number each piece with a waterproof black ink, such as India ink.

The least expensive hand lens is the kind that is molded in one piece from clear plastic. This is quite satisfactory for beginners.

The hydrochloric acid should be a dilution of 1 part concentrated acid to 5 parts water. Distribute this to the students in 1-oz square dropping-bottles. Paper towels should be available for drying the rock specimens after testing for carbonates.

Step B Using the features you noted in **A-2**, separate the specimens of sedimentary rocks in your collection from the others. Set the others aside for study in Step C. Examine your specimens of sedimentary rock.

3. Other than color, what is the most obvious feature that varies from sample to sample?

Grain size

4. Arrange your collection in a sequence based upon the feature noted in **B-4**.

5. Recognition of the cementing substance in a sedimentary rock requires careful chemical analysis. One of the common cementing agents reacts visibly with dilute hydrochloric acid, producing bubbles of carbon dioxide. What is the name of that cementing agent?

(**Calcium carbonate, calcite, or limestone are acceptable answers.**)

The limestones should be set aside. If marble was included in the collection, most students will include it here. Its metamorphic character will not be recognized by beginners.

6. Test each of your specimens with 1 drop of dilute hydrochloric acid. Set aside those that produce the reaction noted in **B-6**.

7. With the aid of Appendix II in your textbook, determine the name that best applies to each of your samples of sedimentary rock.

Separation of crystalline rocks into igneous and metamorphic types is not easy. Some of the gneiss-type rocks in small fragments look very much like igneous rocks. Both marble and quartzite may be grouped by the students as sedimentary because of the uniform grain size and composition.

Step C Some kinds of crystalline rock are easily recognized, while others are not. Geologists themselves have different opinions about some specimens. The fact that a specimen is igneous or metamorphic is sometimes almost impossible to decide, especially if the sample is only a fragment.

8. What feature will you use to select the crystalline rock fragments that you think are igneous rock?

The random distribution of different minerals is a primary clue to igneous rocks.

9. What features will you use to identify the specimens of metamorphic rock?

Specific minerals tend to be somewhat sorted in most metamorphic rocks. The exceptions are those such as marble and quartzite, which are composed of a single mineral.

10. Sort your collection of crystalline rock samples into three groups: those you are sure are igneous, those you are sure are metamorphic, and those of which you are uncertain.

11. Study the rock samples that you feel certain are igneous and compare them with the information in Appendix II of your textbook. Decide what you are going to call each sample.

12. Repeat **C-12** with the samples you are sure are metamorphic rocks.

13. Using the knowledge you have gained through the studies you made for **C-12** and **C-13** and the samples you have named, decide upon your "best guess" for the rock names of the samples that puzzled you.

Step D For each sample that was given to you, write a statement patterned after this one: "I believe sample X is a sandstone because it appears to be composed of cemented sand grains and the cement does not react with dilute hydrochloric acid."

The statements made will depend upon the collection used.

I believe sample ________ is a ________________ because

____

____

I believe sample ________ is a ________________ because

____

____

I believe sample ________ is a ________________ because

____

INVESTIGATION 5-2—

Calcium carbonate ($CaCO_3$) plays a considerable role in the production of sedimentary rocks. Its chemical characteristic is that the bicarbonate, $Ca(HCO_3)_2$, is quite soluble in water, while the normal carbonate is relatively insoluble. The presence of carbon dioxide in water produces carbonic acid (H_2CO_3). This weak acid reacts with the carbonate radical (CO_3^{--}) and produces the bicarbonate radical (HCO_3^{--}). Thus, carbon dioxide produced through decay, respiration, or other natural methods plays a major role in forming limestones of all varieties, including those found in caves, in travertine, and in the shells of mollusks, many crustaceans, some algae, and numerous other life forms. Therefore, the reaction by which calcium carbonate is converted to the bicarbonate and back to the normal carbonate is a very important one.

STEP A—

Students tend to use too much powdered calcium carbonate. All that is needed is a few milligrams, just enough to cover the very tip of a pointed knife. After the powder has been added to the water in the test tubes, it may float. Powdered shell usually will become wet and sink immediately, but powdered chalk will not. If this happens, close the test tube with your thumb and shake vigorously. The suspension of powdered chalk will make the water slightly milky.
The volume of breath introduced through the soda straw must be controlled carefully. Blowing should be continued until the water clears. If too much powdered material has been added, the water will never become completely clear. However, there will be a noticeable reduction in the milkiness.

NO. 1—

Usually a little material will be left. However, if a sufficiently small amount of powdered shell was introduced initially all of it will disappear.

NO. 2—

There will be no noticeable change in the test tube that was set aside. Actually, a trace of the material will have dissolved.

____

I believe sample ________ is a ________________ because

____

____

I believe sample ________ is a ________________ because

____

____

I believe sample ________ is a ________________ because

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I believe sample ________ is a ________________ because

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I believe sample ________ is a ________________ because

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I believe sample ________ is a ________________ because

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I believe sample ________ is a ________________ because

____

____

Effect of Carbon Dioxide and Water on Shell Material

Aim: To explore the effects of carbon dioxide and water on shell material

MATERIALS
Powdered shell material
Test tubes (4)
Soda straws
Bunsen burner
Water

Although we have specified powdered shell material in the student's manual, it is not necessary that this be made from shells. Perhaps the best material to use is precipitated chalk (calcium carbonate), which occurs in a finely powdered state and is likely to be found in the chemistry laboratory. An ounce of it will be enough to supply a class of 30 for several years. We have found that when natural shells are used, partly weathered fragments work better than fresh shells. This is because weathered shells have lost some of the organic materials they originally contained.

The test tubes should be approximately 5/8″ x 6″.

It is best to use distilled water in this investigation. Hard water may already be nearly saturated with calcium bicarbonate, or it may be so charged with sulfates that the calcium will be precipitated as a sulfate as rapidly as it goes into solution as the bicarbonate. Some treated waters contain a large amount of hydrochloric acid, formed during chlorination. This also interferes with the reaction. Rainwater is a good substitute for distilled water.

Step A Put a tiny pinch of powdered shell in each of 2 test tubes. Add water to fill each test tube half full. Set one of these test tubes aside. By means of a soda straw, blow into the water in the other test tube. Be sure that the lower end of the straw is not more than ½ inch from the bottom of the test tube. Blow gently enough to prevent the water from splashing out of the test tube. Blow for 5 or 6 minutes.

1. How much of the powdered shell disappeared into solution in the test tube into which you blew? Check the correct answer.

( ) None ( ) Some (✓) All

2. How much of the powdered shell disappeared into solution in the test tube that you set aside?

(✓) None ( ) Some ( ) All

Step B Let the test tubes stand until the powdered shell has settled to the bottom. Very carefully pour off half the water from each into clean, dry test tubes. Heat these test tubes over the Bunsen burner.

The decanting must be done carefully. None of the residue should be transferred to the clean test tube. Heating need not be continued after the solution first starts to boil. During heating, the test tube should be agitated gently to prevent a steam bubble from forming at the bottom and forcefully expelling the contents.

3. What happened to the water from the test tube into which you blew?

This test tube's contents became slightly cloudy as the bicarbonate decomposed upon heating. The resulting calcium carbonate is so finely divided that it settles very slowly.

4. What happened to the water from the test tube into which you did not blow?

It remained clear.

5. Explain what you think happened in this experiment.

The carbon dioxide of the breath reacted with the water and formed carbonic acid. This, in turn, reacted with the calcium carbonate and produced soluble calcium bicarbonate. When heated, the unstable calcium bicarbonate decomposed, producing calcium carbonate, water, and carbon dioxide. Since the latter is practically insoluble in hot water, it escaped.

TEAMS FOR INVESTIGATION 6-1

It is best to divide the class into teams of three, one student to be the "dropper," a second the "timer," and a third the "recorder." The same timer should be used throughout the series. This is important because of timing idiosyncracies. It is good to have the timers practice using the stopwatch beforehand. They should slightly depress the start-and-stop button of the watch just before starting to time a drop, and again just before stopping the watch when the object strikes the bottom. This will reduce the lag time of the trigger mechanism of the watch. Accuracy of timing is critical. The times will be in the vicinity of 1 and 2 sec.

This very simple experiment, or demonstration, teaches two fundamental facts about the rates at which sediments settle in still water: (1) when mass and density remain unchanged, the settling rate varies with shape; (2) when density and shape remain unchanged, the settling rate varies with mass. The physics of the experiment is far too complicated to explain to the students. It revolves around the formation of boundary layers, the turbulence, and the viscosity of the fluid. A more advanced demonstration is appended.

Effect of Particle Shape on Settling Rate

Aim: To discover whether the shape of a particle affects the rate at which it settles in water

MATERIALS
Glass cylinder Water Modeling clay Stopwatch

The authors use a 1-liter graduated cylinder filled with tap water to a depth of 40 cm. However, you can use a 32-inch plastic tube, or a similar tube, which can be purchased at a plumbing shop.

Any of the permanent types of modeling clay, such as Permaplast or Plasticine, work well. Each team should be given about 20 g. Very likely you can obtain clay from the elementary schools of your system or from your art department.

Stopwatches are necessary, preferably those that will time to 0.1 sec. You can probably borrow them from the physics department or the athletic department.

Step A Roll the modeling clay into a cylinder that is 5 inches long and has a uniform diameter. Cut the clay cylinder into 10 equal pieces. Roll each piece into a ball.

1. Fill the glass cylinder with water to about 1½ inches from the top. Measure from the outside the depth of the water. What is the depth?

_______________cm

STEP A—

The length of the water column will vary with the apparatus used. Columns of the same length, ±3 mm, should be used in each step.

Step B Hold a ball of modeling clay so that it just touches the water. When the timer is ready, let go of the ball. Note on the stopwatch how long it takes the ball to reach the bottom of the water. Record the results of 10 trials, one with each ball, in the following table.

2.

Trial 1	_______________sec	Trial 6	_______________sec
Trial 2	_______________sec	Trial 7	_______________sec
Trial 3	_______________sec	Trial 8	_______________sec
Trial 4	_______________sec	Trial 9	_______________sec
Trial 5	_______________sec	Trial 10	_______________sec

Sum _______________sec

Average _______________sec

The authors' mean time of settling through a 40-cm column of water, using clay balls weighing about 2 g, was 1.48 sec. The individual times ranged from 1.4 to 1.6 sec.

3. How would you describe the path of a ball as it falls through water?

The path is reasonably direct, with a slight wobble from side to side.

Step C Recover the 10 modeling-clay balls and flatten each one into a disk about the size of a nickel. Repeat Step B and record the results.

The authors' mean time of settling through a 40-cm column of water was 2.94 sec. The individual disks settled at between 2.5 and 3.2 sec.

4.

Trial 1	______ sec	Trial 6	______ sec
Trial 2	______ sec	Trial 7	______ sec
Trial 3	______ sec	Trial 8	______ sec
Trial 4	______ sec	Trial 9	______ sec
Trial 5	______ sec	Trial 10	______ sec

Sum ______ sec

Average ______ sec

5. How would you describe the path of a flat disk as it falls through the water?

It flutters through the water no matter how it is held before dropping.

Step D Study the results of the experiments performed in Steps B and C.

6. In which experiment did the objects fall more rapidly?

Step ___B___

7. In which experiment was there greater variation in the amount of time it took the individual objects to fall through the column of water?

Step ____C____

8. Does the shape of an object affect the time it takes to settle in water?

____Yes____

9. Why do you think the shape of an object affects its settling time in water?

Most students will note that there was a marked difference in the path of the settling object, that the ball settled "straight down." A few students may say that the disk had more surface and therefore was retarded more by friction with the water. Both of these are acceptable answers; they contain a germ of the truth.

____

____

____

____

____

____

Step E Combine two of your clay pieces into one and roll it into a ball. Do this with all your material, making 5 balls. This will produce balls that have about twice the mass of those you used in Step B. Repeat Step B with these objects.

10.

The authors' average time with approximately 4-g masses was 1.23 sec. The individual variation was from 1.1 to 1.4 sec.

Trial 1 ____________sec

Trial 2 ____________sec

Trial 3 ____________sec

Trial 4 ____________sec

Trial 5 ____________sec

Sum ____________sec

Average ____________sec

11. Compare the result of Step E with that of Step B. What was the average time in Step B?

The results will vary from team to team.

____________sec

NOTES—

If some students finish early, they should be encouraged to experiment with the settling rates of other shapes, such as cubes, tetrahedrons, cones, or cylinders. They should also do settling experiments, using objects with different masses but with the same shape and composition. If large ball bearings are available, some students should test the effects of density by using modeling-clay spheres and ball bearings of the same size.

DEMONSTRATION—

Wash a large ball bearing with detergent and warm water to make it absolutely free of grease and oil. Hold the bearing in fine-tipped forceps and paint it with a concentrated solution of methylene blue or water-soluble ink. When this is dry, drop the painted bearing into a cylinder of water. As the dye washes off, it will trail behind the bearing and outline the turbulence. The viscosity of the water can be increased by adding *small* amounts of methyl cellulose suspension. In this way, the settling rate will be decreased and the turbulence will be more apparent.

INVESTIGATION 6-2—

If you live in an area where there are fossil-bearing strata, bring in a box of local rock samples containing fossils and have the students examine them. Emphasize that most fossil material is fragmentary and that reconstruction of a fragment requires patience and knowledge. If you have any students who seem intensely interested, get some abandoned dental chisels and scrapers from a dentist. Let your interested students try to expose a fossil with these tools. Fossils that are embedded in shale are the easiest to reveal. Limestone, however, makes the most enduring permanent specimen. Over the years, you can accumulate a fine selection of material for classroom demonstration.
If there is a stratum of eroding shale nearby, gather some of the material that has been reduced to a fine claylike powder. "Pan" this in a petri dish or in a small aluminum pie plate by swirling a tablespoonful of the debris in water. When it is spread out in a thin layer, examine the debris with a 10× hand lens or a low-power binocular microscope. Usually you will find microfossils, especially Bryozoa and Mollusca. There may be bits of coral or larval trilobites if the material is from the Early Paleozoic Era.

What was the average time in Step E?

__________ sec

12. In which step did the balls settle more rapidly?

Step E

13. Did the density of the objects you used change from Step B to Step E? Why?

No. The same material was used in each step.

14. Did the shape of the masses differ materially between Step B and Step E? Why?

No. In both cases the objects used were essentially spheres.

15. What did change between the two experiments?

The mass and the settling time

16. Make a general statement summarizing your results of the entire series of experiments.

When objects of the same density and mass but of different shape settle in water, their settling rate depends upon the shape. When objects of the same shape and density but of different mass settle in water, their settling rate depends upon the mass.

A laboratory exercise on fossils per se is not included because, to be meaningful, it would require entirely too much previous knowledge of the subject. If you have the material prepared for ESCP by Hubbard, you can use the plastic cast of brachiopods for a study of variation in a population. If an exercise on fossils is to be meaningful, one must be well informed about the statistics of variation. If you are familiar with the derivation of standard deviations and the students are able to understand and to derive a standard deviation, then by all means build an exercise around the variation of brachiopods. (*See page 42.*)

INVESTIGATION 6-2

Constructing a Geologic Column

Aim: To construct a geologic column

When a geologist constructs a geologic column for a region such as a county or a state, he combines data from many areas into one column. Each of the short local columns is called a section. Pages 67–69 in your textbook describe how a column is made from sections. Use them as a guide while you work on this investigation.

Look at Figures 1–4. They are diagrams of sections from 4 sites that are within a mile of one another. Each section shows the sequence of rocks it contains. The rock symbols used are those that are generally accepted by geologists. The interpretation of the symbols is shown in Figure 5. Sometimes two different symbols seem to overlap. This means that the rock is an intermediate of the two types. Thus, the symbol for limestone overlapped by the symbol for sandstone indicates "sandy limestone." Fossils were found in each of the columns. Their presence is indicated by letters, with A as the oldest and F the youngest (see Figure 6).

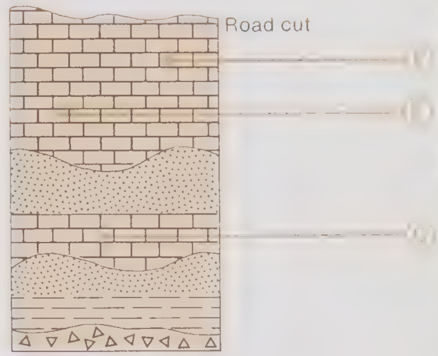


Figure 1

Figure 2

Step A Carefully study each section. By comparing the fossils and their position in the sections, decide which section represents the lowest part of the geologic column that you are constructing.

1. Which section contains the oldest rocks and fossils?

   Section 3

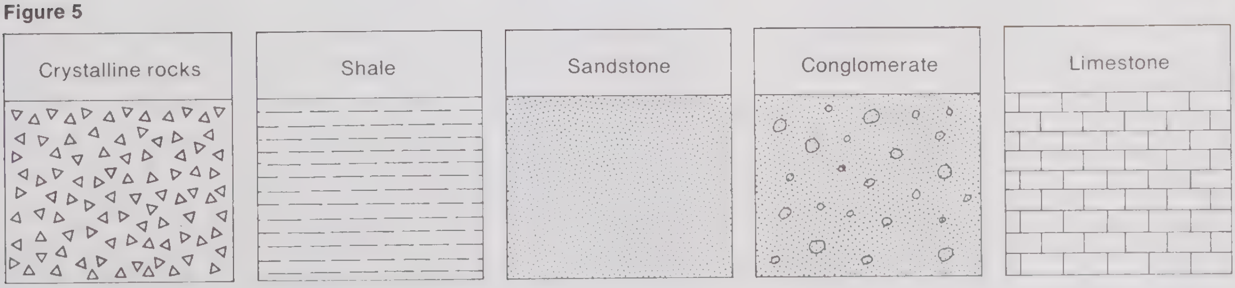
2. Which section contains the youngest rocks and fossils?

   Section 4

3. Which section contains both the oldest and the second youngest rocks in the column?

   Section 1

Figure 5



In evaluating the students' geologic columns, be lenient about the widths they use for each horizon but strict about the sequences.

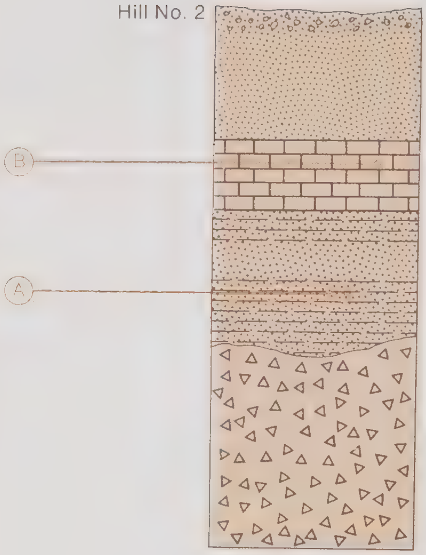


Figure 3

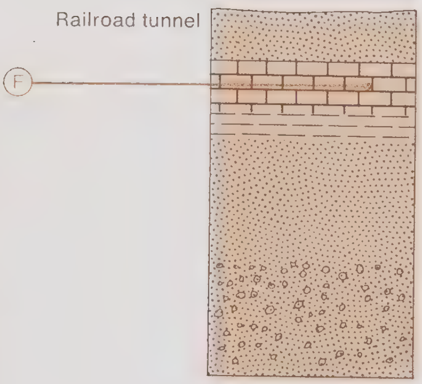


Figure 4

4. Which section connects the section showing the oldest rocks with that showing the youngest rocks?

Section 2

Step B Now you are ready to build the geologic column. Transfer the information from the oldest section to the bottom of the area labeled "Geologic Column" at the right edge of Figure 7. Label each stratum in the column with the name of the type of rock represented. You need not fill the whole area with the symbol for the rock. Add to your column the additional information from the section you noted in your answer to **A-4**.

5. Why do you plot the additional material from this particular section next?

Section 2 overlaps both Section 3 and Section 4 with respect to the age range of the rocks. Near its base, Section 2 contains a fossil found only in the oldest section, Section 3. The sequence of rocks in the upper part of the oldest section, Section 3, is repeated in the lower part of Section 2.

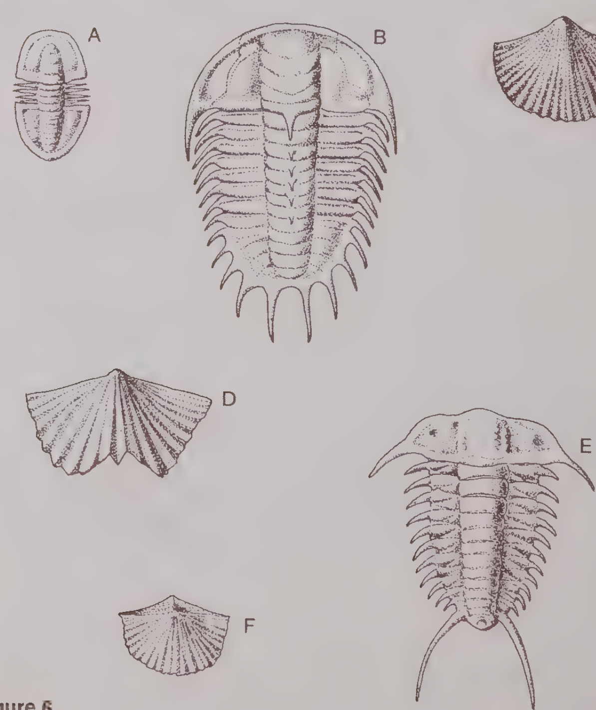
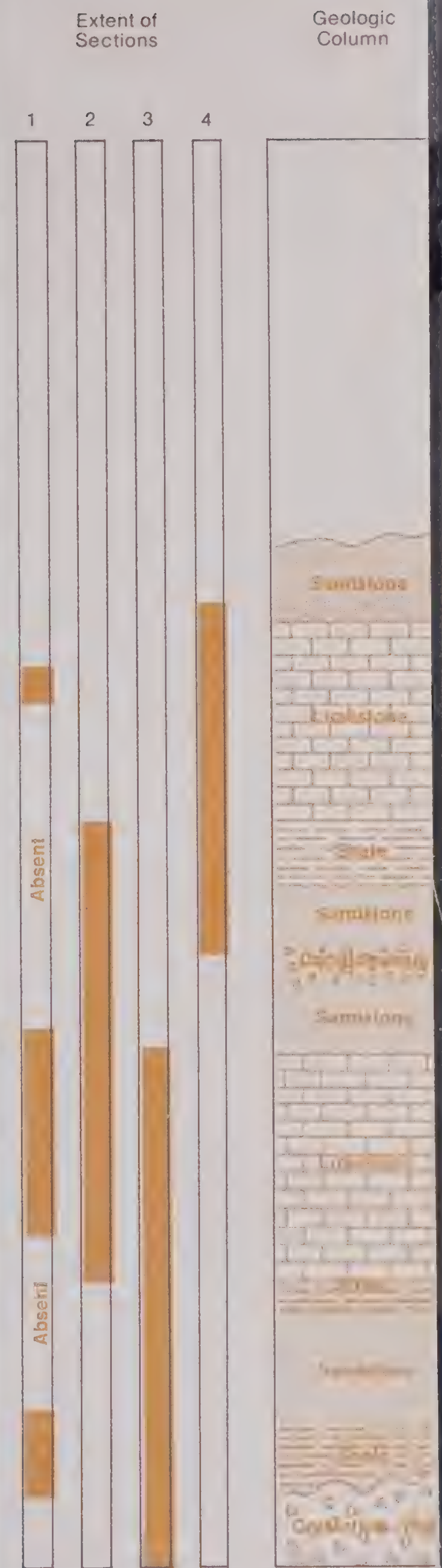


Figure 6

Step C Complete your geologic column. To the left of it, you will find four very slender columns. Blacken the part of the slender column labeled 1 to indicate the distance Section 1 represents of your complete "Geologic Column." The rocks and fossils in Section 1 will give you a clue. Do this for all four sections.

6. Why have you blackened two unconnected parts in slender column 1?

There is an unconformity in the rocks found in the road cut from which Section 1 was drawn.



Figure

INVESTIGATION 8-1—

It is hoped that this investigation will impress upon the students that the number of atoms that will decay in a half-life is not fixed. The half-life period is the time during which half of the atoms that were initially present will decay. Estimation of the half-life of an isotope is not so easy as it seems. For example, the best estimate of the half-life of radiocarbon in the 1940's was about 5,565 years. The current estimate is about 5,770 years. The change came about through more precise measurement of two quantities: the initial amount of C-14 used and the number of atoms decaying in a short, fixed period of time. A much more striking change in the value of a half-life occurred with tritium, an isotope of hydrogen having three times the ordinary mass. The 1940 estimate, which was used for almost 20 years, was that tritium had a half-life of 31 years. Today we consider its half-life to be 12.26 years.

The Meaning of the Term Half-life

Aim: To examine the meaning of *half-life*

MATERIALS
Identical objects; use marbles, ball bearings, matchsticks, or seeds (256)
Box to hold these objects

Almost any small object may be used, provided you can obtain a sufficient number. A package of dried peas or beans or several boxes of paper clips will do if you cannot collect enough marbles or ball bearings. Ideally, each student should do the experiment. A pound of dried peas will supply enough material for a class of from 20 to 25. In addition to the individual boxes that represent crystals, a larger box should be available in which to collect the decayed atoms.

Step A It is often difficult to understand the meaning of the term *half-life* as it applies to radioactive elements. In this investigation you will demonstrate what this term means. It will take several days to complete the investigation. The box represents a crystal that contains radioactive atoms, all of the same kind. The 256 identical objects represent these atoms. We will assign a half-life of one day to this particular kind of radioactive atom. Each day, half of the atoms in the crystal will decay. Each day, remove from the box half of the objects that are there. Those that remain represent the undecayed atoms.

STEP A—

The secret of success with this experiment is *accurate* counting.

1. How many atoms will decay during the first day?

128

Step B On the morning of the second day, remove the proper number of decayed atoms, which you indicated in **A-1**. Each morning, remove the proper number of decayed atoms and record the appropriate data in Table I.

The 256 objects will be reduced to 1 on the morning of the ninth day. The table, however, goes on to the tenth day. It is recommended that the decayed objects be removed each day instead of the whole experiment being done in half an hour. This will help to impress the time element upon the students.

TABLE I

Day of experiment	Number of radioactive atoms at beginning of this day	Number of atoms that decayed during this day
1st day	256	128
2nd day	128	64
3rd day	64	32
4th day	32	16
5th day	16	8

6th day	8	4
7th day	4	2
8th day	2	1
9th day	1	?
10th day	?	?

When only 1 atom remains at the beginning of the day, there is a 50-50 chance that it will decay during that day. The day during which it will decay is determined by pure chance. This is true of *any* individual radioactive atom. Coin flipping or any other method of getting a random "yes" or "no" response may be used. In one experiment, we ran five heads in succession! If each member of the class performs the experiment, the pattern of the results from the tenth day on should impress upon the students that the day on which the last atom will decay is purely a matter of chance.

Step C The problem that faces us is this: What happens when only 1 radioactive atom is left?

2. What is the definition of the term *half-life*? (If you don't remember, see page 101 in your textbook.)

The amount of time necessary for half of the radioactive atoms to decay

3. When the number of atoms is reduced to 1, there is only a 50-50 chance that the one atom will decay in the next half-life. We will let the flip of a coin decide whether the atom decayed. We will say that if the coin lands heads up, the atom did not decay, and if it lands tails up, the atom did decay. Beginning the morning after the day when only 1 radioactive atom is left, determine by flipping a coin whether the atom decayed. Each morning, make the decision according to the flip of a coin and enter the results in Table I.

NOTE—

This experiment may be varied so that it will more nearly represent the natural event of radioactive decay. For example, you may determine the daily fate of each atom by flipping a coin. Shake 32 pennies and spill them on the desk. Count heads and tails. Do this 8 times and total the number of heads and tails. The number of tails represents the number of atoms to be removed at the onset of the second day. From there on, the total number of pennies flipped must equal the number of atoms remaining in the crystal. By comparing the table from Step B with data accumulated this way, you can see that if there are only a few atoms present initially, the decay does not follow the half-life rule but only approaches it. The rule operates only for very large numbers—million of atoms.

Step D One way to discover how many radioactive atoms will remain after a certain period of time has elapsed is to make a table like Table I, which you derived experimentally. However, it would be useful to have a quicker way to find this information. Let us examine the data in Table I. How could you arrive at the number of radioactive atoms left at the beginning of the fourth day by direct calculation? You know that each day the number was reduced by one half. We can indicate this mathematically as $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$, because four decay periods had passed. Another way to write it is in power; thus, $\frac{1^4}{2^4}$ also represents four decay periods. 1^4 is 1 and 2^4 is 16; therefore, 1/16 of the original atoms should be present after 4 half-life periods.

4. Is the number of radioactive atoms you entered for the beginning of the fourth day 1/16 of the number you started with? Prove it.

Yes

This investigation is best done using teams of two, one to perform the investigation and the other to take notes.

Force Needed to Overcome Friction

Aim: To discover the force needed to overcome friction

MATERIALS
Board, 6″ x 1″ x 30″
Block of wood, 2″ x 4″ x 6″, with a screw eye in one end
Spring scale
Piece of coarse sandpaper, 6″ x 8″
Meterstick
Piece of string, 10″ long

The boards can be made easily in the school manual training shop. Ordinary finished 1″ x 6″ lumber is satisfactory. The patch of sandpaper used in Step C should be stapled on one side near one end of the board. If rough-sawed lumber is available locally, one side can be planed smooth and the other side will be rough enough to use without sandpaper.
The wooden blocks should be cut from finished 2″ x 4″ lumber.

Step A Place the board flat on your desk, with the smooth side up. Place the block of wood on one end of the board so that the screw eye points toward the other end of the board. Tie one end of the string to the screw eye and make a loop in the other end. Hook the spring scale into the loop. Check Figure 1 to be sure you have assembled the apparatus correctly.

1. Slowly pull at the block with the spring scale. Observe the stress, which is the number of grams of pull that is needed to start the block sliding. Your action overcame static friction. What amount of force, in grams, is needed to overcome static friction?

______________g

2. Again pull the block along the board. This time, note the least amount of pull necessary to keep the block moving after you have overcome static friction. What amount of force, in grams, is needed to overcome kinetic friction?

______________g

The answers to this will vary from block to block and from board to board. The kinetic friction will be less than the static friction. Both will be related to the mass of the block, the area of the block that is in contact with the board, and the smoothness of both the block and the board.

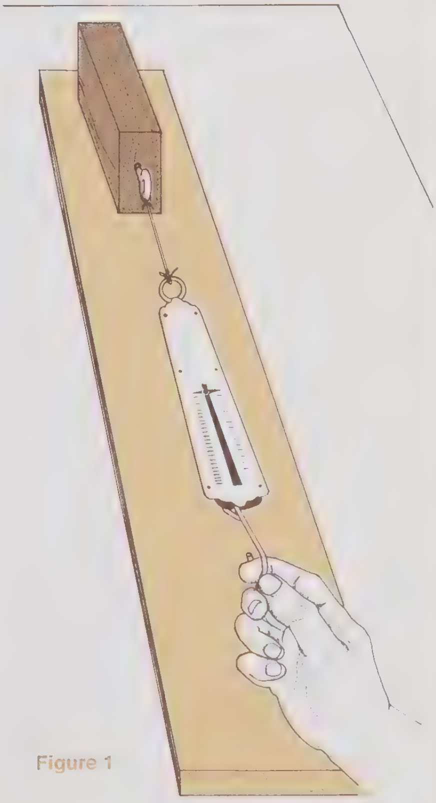


Figure 1

Step B Repeat Step A, with this change: Place two or three textbooks under one end of the board to produce a slope.

3. What amount of force is necessary to overcome static friction now?

______________g

4. What amount of force is necessary to overcome kinetic friction now?

______________g

5. Were the forces applied in **B-3** and **B-4** greater, or less, than those applied in **A-1** and **A-2**?

Less

6. What caused this change in the amounts of force?

The force of gravity

Step C Repeat Step A. This time, use the other side of the board, and place the block of wood on the end with the sandpaper.

7. What amount of force is necessary to overcome static friction?

________ g

8. What amount of force is necessary to overcome kinetic friction?

________ g

9. Were the forces applied in **C-7** and **C-8** greater, or less, than those applied in **A-1** and **A-2**?

Greater

10. Explain the cause for your answer in **C-9**.

Friction is greater on a rough surface than on a smooth surface.

INVESTIGATION 9-2—

sample is nothing more than a large-size, 14-oz., frozen-fruit-juice container filled with cement mixture and allowed to harden. Any packaged cement mix that can be found in a hardware store will suffice. The holes into which the thermometers are placed can be made in either of two ways: (1) Two dowels a little larger in diameter than the thermometers to be used should be dipped in melted paraffin until they have a reasonably thick coating on their surface. (See Figure 2 for a method of supporting the dowels.) When you fill the can with the cement mixture, allow the dowels to drop gently the rest of the way into place. The next morning, remove them with a twisting pull. In about a week the cement will be wholly dry. (2) This is a quicker and easier method of putting the thermometer wells into the cement. Fill the can with the cement mixture and set it aside for two days. Use a cement twist drill a little larger than the diameter of the thermometer and of sufficient length. With a drill press, drill the central hole to the required depth; then drill the marginal hole. Have one of your students who is adept in the shop, or the shop instructor, do this for you.

The cement "rock" has many of the physical characteristics of a piece of limy sandstone.

Use teams of four, as described in Step B.

Accurate measurements of the rate heat travels in a substance are difficult to make. In this investigation the subject is approached in a qualitative, rather than a quantitative, way. The experiment also presents the challenge of graphing numerical data and then using the graph. In general, a 40-to-45-minute period will be necessary for both the water and the rock to reach equilibrium at the boiling point of water.

INVESTIGATION 9-2

Rate of Heat Transmission in Rock and in Water

Aim: To determine and compare the rate of heat transmission in rock and in water

MATERIALS
Special "rock" sample
Thermometers (3)
1-liter beaker
Asbestos-gauze mat
Pipestem triangle
Tripod or ring stand with large ring
Watch with second hand
Bunsen burner
Water

With the exception of the "rock" sample, all the equipment needed is standard in the chemistry laboratory and should be borrowed. Any watch with a second hand is acceptable. If the classroom is equipped with a wall clock that has a sweep-second hand, everyone should use it. The investigation can then be run with a single timer for the entire class.
The special "rock" sample should be prepared well ahead of time. Once made, these will last for years. The (*See page 50.*)

Step A Set up the apparatus as shown in Figure 1. Lower the "rock" into the beaker so that it rests firmly on the pipestem triangle. Put enough water into the beaker to bring the level to approximately ½ inch from the top of the rock sample. *Carefully* lower a thermometer to the bottom of each hole in the rock sample. Lower a third thermometer into the water.

Be sure that the thermometers are lowered carefully, not dropped, into the well in the rock.

1. Read and record below the temperatures of the water and the rock. Read these to the nearest ½°C.

Temperature of rock, near margin ____24____°C

Temperature of rock, near center ____24____°C

Temperature of water ____22.5____°C

The two temperatures will be very close if the water has been in a container in the room for several hours. Otherwise, there may be a difference of several degrees at the start. It is preferable to start with essentially the same temperatures.
(The author's data is given as an example.)

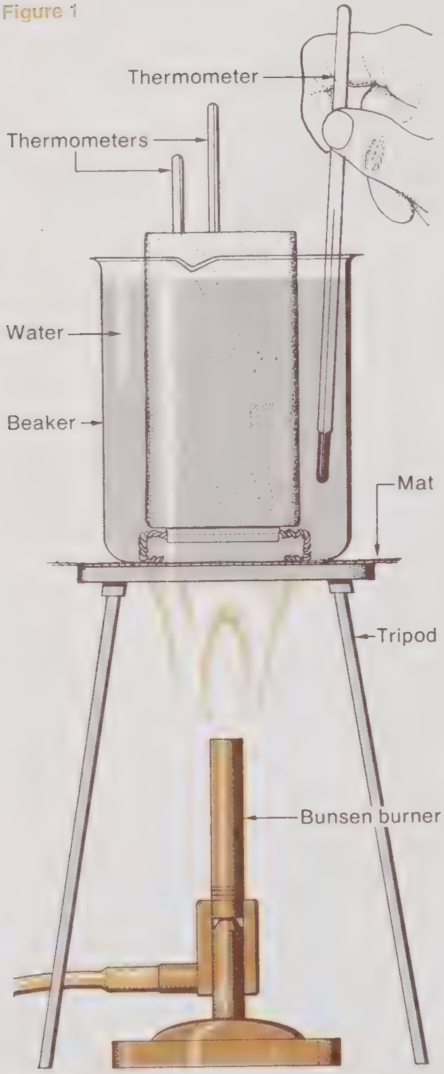
Step B In this investigation you will be required to note and record the temperatures of the water and the interior of the rock sample at two places over a period of time while they are being heated. Two of you will read the temperatures of the interior of the rock. Another will carefully stir the water with a thermometer and read its temperature. The fourth will be the timer-recorder. You will read the temperatures every 30 seconds.

Light the Bunsen burner and place it under the beaker containing the water and the rock sample. Start timing when the Bunsen burner is placed under the beaker. Start stirring the water *GENTLY* at the same time.

If a central timer is being used for all teams, the Bunsen burners should be lighted away from the beakers they are to heat. On the order "Start," all burners should be put under the beakers. At that time the temperatures should be taken and entered for 0:00 time. Continue the heating for 10 or 15 minutes.

(These tables will vary a little from team to team. See the following results of an experiment that was carried on for 10 minutes to estimate the results the students should get.)

Figure 1



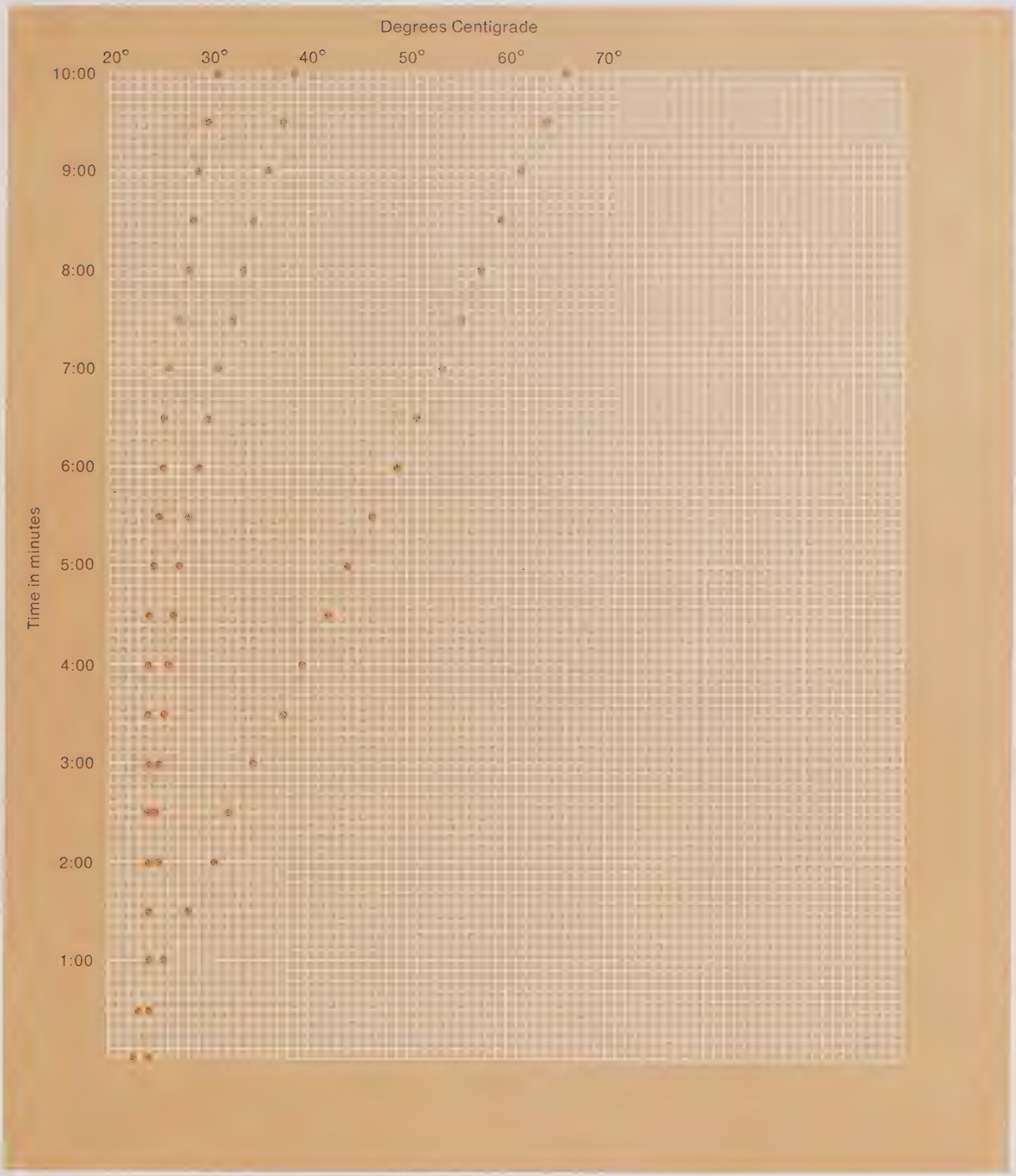
2. At the end of each 30 seconds, the timer will call "Mark!" The thermometer readers will make note of the temperatures at that time and report them to the timer-recorder, who should write them in the appropriate place in Table I.

TABLE I

	Temperature				Temperature		
Time	Water	Rock Margin	Rock Center	Time	Water	Rock Margin	Rock Center
0:00	21.5	[illegible]	[illegible]	7:30	55.5	32.5	27.0°C
0:30	23.0	24.0	24.0°C	8:00	57.5	33.5	28.0°C
1:00	25.5	[illegible]	24.0°C	8:30	59.5	34.5	28.5°C
1:30	28.0	[illegible]	24.0°C	9:00	61.5	36.0	29.0°C
2:00	30.5	[illegible]	24.0°C	9:30	64.0	37.5	30.0°C
2:30	[illegible]	24.5	[illegible]	10:00	66.0	39.0	31.0°C
3:00	[illegible]	25.0	[illegible]	10:30			
3:30	37.5	[illegible]	[illegible]	11:00			
4:00	[illegible]	[illegible]	[illegible]	11:30			
4:30	[illegible]	26.5	[illegible]	12:00			
5:00	44.0	[illegible]	[illegible]	12:30			
5:30	46.5	[illegible]	25.0°C	13:00			
6:00	49.0	[illegible]	[illegible]	13:30			
6:30	51.0	[illegible]	[illegible]	14:00			
7:00	53.5	[illegible]	[illegible]	14:30			
				15:00			

Step C The other team members should transfer the data to their laboratory books. Plot the data on the graph paper included in this investigation.

All temperature plots will produce curves that increasingly approach straight lines. The graph below represents the authors' data. It shows the general rates of temperature change you can expect.



3. What was the highest temperature recorded for the water?

66 °C

4. How long did it take the water to reach that temperature?

10 min 00 sec

5. What was the highest temperature recorded by the thermometer near the margin of the rock?

39 °C

6. How long did it take the margin of the rock to reach the temperature noted in **C-5**?

10 min 00 sec

7. What was the highest temperature recorded by the thermometer at the center of the rock?

31 °C

8. How long did it take the center of the rock to reach the temperature noted in **C-7**?

10 min 00 sec

9. Did the center of the rock reach the same maximum temperature that the water reached?

No

10. What may be an explanation for your answer to **C-9**?

It took longer for the heat to penetrate to the center, and the center heated more slowly. Possibly, rock transmits heat more slowly than water does.

Step D In this step you will examine the data you have accumulated in order to discover the rates of temperature change in the rock and in the water.

The following is an example.

11. From the data taken near the end of the investigation, select a temperature recorded for the center of the rock. What temperature did you select?

30 °C

12. At what time was the observation in **D-11** made?

9 min 30 sec

13. At what time, from your data or graph, was the margin of the rock at the temperature noted in **D-11**?

6 min 30 sec

14. What temperature was the center of the rock at the time noted in **D-13**?

25.5 °C

15. What was the difference in the temperatures of the margin and center of the rock at the time noted in **D-13**?

4.5 °C

16. How long did it take for the temperature in the center of the rock to make the change noted in **D-15**? (See **D-12** and **D-13**.)

3 min 00 sec

17. What was the change in temperature per minute? (See **D-15** and **D-16**.)

1.5 °C/min

18. Consult your data and graph. At what time was the water at the temperature noted in **D-11**?

1 min 55 sec

19. At what time was the water at the temperature noted in **D-14**?

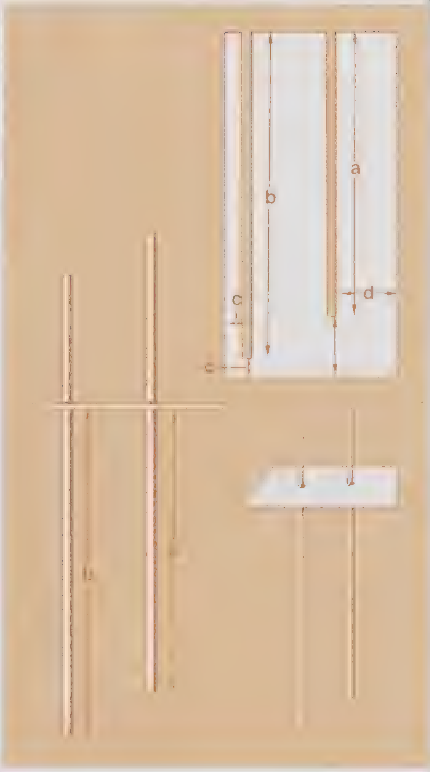
1 min 00 sec

20. How long did it take the water to make this change in temperature? (See **D-18** and **D-19**.)

0 min 55 sec

21. In degrees per minute, what was the rate of change in the temperature of the water?

4.91 °C/min



4.5°C/min if **D-18** is 2 min

22. In which substance did the temperature change more rapidly, the water or the rock?

The water

Step E You know that temperature and heat are not the same. You measured the rate of temperature change in your rock and in water under the conditions of your investigation. Now you will study the rates at which heat flows through water and through your rock.

The authors' data follows.

4.5 cal/min if **D-18** is 2 min

23. In **D-21** you calculated the rate of temperature change in the water. How many calories were supplied per minute to 1 gram of water to produce this change?

4.91 cal/min

24. The specific heat of the rock that you used can be taken as 0.19 cal/g/°C. How many calories are needed to raise the temperature of 1 gram of your rock to 1°C?

0.19 cal

25. In **D-17** you estimated the rate at which the temperature of your rock changed. How many calories per minute were needed to make that change for 1 gram of the rock?

$1.5 \times 0.19 = 0.285$ cal/min

26. Through which substance, water or rock, did heat flow more rapidly? (See **E-23** and **E-25**.)

Water

This is the standard laboratory exercise for measuring the specific heat of a solid. It depends upon the transfer of heat from the solid to water. The amount of heat is measured by calculating the number of calories needed to make the noted change in the temperature of water.

Specific Heat of Sand

Aim: To measure the specific heat of sand

MATERIALS
Sand
Small empty can
Thermometer, Celsius scale
Balance and weights, metric scale
600-ml beakers (2)
Water
Heat source

Washed sand should be used. If you collect the sand from a sandpit or stream or lake, it will be necessary to wash it free of clay and other debris. Pebbles and larger particles should be removed because they take too long to become uniformly heated.

Step A Before you do this investigation you will need to review the meanings of certain words. If you do not know the terms below, look them up in your textbook.

1. How do you define a calorie?

A calorie is the amount of heat necessary to raise the temperature of 1 g of water 1°C.

2. How do you define specific heat?

Specific heat is the number of calories needed to raise 1 g of a substance 1°C.

Step B In this investigation you will add a known weight of sand at a known temperature to a known weight of water at a known temperature.

The author's experimental data is given below for Steps B–E. Their sand sample contained a great deal of clay and was not completely washed, so their data will serve only as a very rough guide.

3. What is the weight of the can to the nearest 0.1 g?

88.0 g

4. Fill the can with sand to a depth of 1″. What is the weight of the combination to the nearest 0.1 g?

141.0 g

5. What is the weight of the sand? (**B-4** minus **B-3**)

53.0 g

6. What is the weight of one of the beakers to the nearest 0.1 g?

153.3 g

7. Fill that beaker with water about 2 inches deep. What is the weight of the combination to the nearest 0.1 g?

341.8 g

8. What is the weight of the water in the beaker? (**B-7** minus **B-6**)

188.5 g

Step C Heat the sand in its container by putting it into the *second* beaker with enough water to come halfway up the side of the sand container. Be very careful that no water gets into the sand. Place the setup over a heat source and bring the water to a boil. Stir the sand with the thermometer. Do this carefully so that you do not break the thermometer; it is fragile! When the sand has reached 91°C, remove the thermometer.

Step D Place the thermometer in the water that you weighed.

9. Stir gently, and read and record the temperature.

21.0 °C

10. Pour the hot sand into the beaker of weighed water and stir the sand in the water with the thermometer. What is its temperature?

24.2 °C

11. Stir again. What is the temperature now?

24.1 °C

12. Record here the higher of the two temperatures recorded in **D-10** and **D-11**.

24.2 °C

Step E You now have all the information you need to calculate the specific heat of the sand.

13. What was the increase in the water temperature? (**D-12** minus **D-9**)

3.2 °C

14. What weight of water was heated? (See **B-8**.)

188.5 g

15. How many calories were transferred from the sand to the water? (**D-13** times **E-14**)

603.2 cal

16. Where did this heat come from?

The sand

17. What weight of sand was used? (See **B-5**.)

53.0 g

18. How much heat was transferred from each gram of sand?

11.38 cal/g

19. What was the temperature change in the sand? (Step C minus **D-12**)

66.8 °C

20. How much heat was lost by each gram of sand for each degree Celsius? (**E-18** divided by **E-19**)

0.17 cal/g/°C

21. What is the specific heat of the sand? (See **A-2**.)

0.17 cal/g/°C

INVESTIGATION 10-1—

Crystalline copper sulfate, sometimes called blue vitriol, is blue in color because it contains water of crystallization. Anhydrous copper sulfate is almost white; in its absolutely pure state, it is white. This substance is hydroscopic; in other words, it absorbs water readily but does not become wet. Instead, the copper sulfate hydrates and assumes a blue color. This change is used to detect water vapor.

Copper sulfate is poisonous, as is practically every chemical used in the laboratory. It is very bitter and astringent. No student venturesome enough to taste it will swallow much! *If* a student does taste it, have him rinse his mouth several times with water, spitting the water into the sink.

The powdered copper sulfate for distribution to the class is easily prepared by grinding the crystals in a clean porcelain mortar. One or two grams per pupil is ample. The powdered material should be kept in a stoppered bottle until issued. This is especially important in very dry areas. The powdered material will lose water to the air when the relative humidity is low.

Does Air Contain Water?

Aim: To discover whether air contains water

MATERIALS
Powdered copper sulfate crystals
Test tubes (1 or 2)
Bunsen burner
Watch glass
Piece of white paper, or 3″ x 5″ card
Test-tube holder

Step A Place into a test tube about as much powdered copper sulfate as you can pile on a penny. Hold the test tube almost horizontal and gently shake it so that the copper sulfate spreads out evenly along the side of the test tube.

1. What is the color of copper sulfate?

Blue

Step B Using a test-tube clamp, hold the test tube nearly horizontal over the Bunsen burner. Gently shake the tube from side to side so that all the material is well heated.

The thinner the layer of hydrated copper sulfate in the test tube, the more nearly anhydrous the end product will be. Heating must be continued until all blue color is lost throughout the mass. This is an important step. Heating must be continued until all water is driven from the copper sulfate *and* from the walls of the test tube.

2. As heating progresses, what happens to the color of the copper sulfate?

It loses its blue color and becomes grayish-white.

3. What forms on the inner wall of the test tube near the cool open end?

Water droplets

4. What is the probable source of what you observed in **B-3**?

The water droplets are produced by the cooling of the water vapor that was driven off from the hydrated copper sulfate.

5. Continue heating until the test tube is free of everything except the copper sulfate. This is called anhydrous copper sulfate.

Step C Transfer a little of your anhydrous copper sulfate to a second test tube or a watch glass. Add one drop of water to the material.

6. What happens?

Both the material and the water become blue. Copper sulfate is soluble in water.

7. What does this change indicate?

When water is added to white, anhydrous copper sulfate, it becomes blue. It also shows that blue copper sulfate contains water.

8. How can you test for the presence of water in air?

Expose anhydrous copper sulfate to the air; if water or water vapor is present, the white, anhydrous copper sulfate will change to blue, hydrated copper sulfate.

Step D To test your hypothesis stated in **C-8**, place a small amount of anhydrous copper sulfate on a piece of white paper or on a watch glass.

9. Breathe across the anhydrous copper sulfate. What happens?

It becomes blue.

10. What does this result suggest?

Breath contains water.

11. In what state is the water?

It is water vapor, or it is in the gaseous state.

12. Where did it come from?

It came from the moist tissues of the respiratory tract or, more simply, from the lungs.

Breath is saturated with water vapor at body temperature. Very quickly the anhydrous copper sulfate will absorb enough water to become hydrated.

Step E Place the rest of your anhydrous copper sulfate on a watch glass or on a piece of white paper. Leave it there until the next class.

13. What happened to the color of the anhydrous copper sulfate?

14. How do you explain this?

STEP E—

In humid regions or during rainy weather in most areas, the relative humidity is high. Under those conditions the anhydrous copper sulfate will become blue in as short a time as a half hour.

The answer to this question will vary with the relative humidity, from blue in damp areas to pale-blue in drier regions. In desert regions there may be no change at all.

If the answer to **E-13** was "blue or pale-blue," the anhydrous copper sulfate absorbed water vapor from the air and changed to blue, hydrated copper sulfate. If the answer to **E-13** was "no change," there was no moisture in the air to be absorbed.

Many minerals contain water of hydration. One of the common rock-forming minerals is gypsum, a hydrated form of calcium sulfate. This investigation is introduced here to show that not all water at the earth's surface is easily discernible. The investigation has no direct relation to Chapter 10 and may be used elsewhere if desired.

INVESTIGATION 10-2

Does Dry Rock Contain Water?

Aim: To determine whether a dry rock contains water

MATERIALS
Piece of gypsum
Mortar and pestle
Bunsen burner
Hard-glass test tube
Test-tube holder

Gypsum is easily procured and is most desirable. However, crystallized washing soda or a piece of gypsum board from which the cardboard is stripped may be substituted. All other materials and equipment are common laboratory items. A small amount of anhydrous copper sulfate will be needed if any of your students want to test the fluid produced in this brief investigation.

Step A Examine the piece of gypsum. Feel it and squeeze it. The chemical formula for gypsum is $CaSO_4 \cdot 2H_2O$.

1. Does the gypsum feel wet? No

2. Can you squeeze any water from the gypsum? No

Step B Put the gypsum in the mortar and use the pestle to grind it to a powder. Pour enough powdered gypsum into a hard-glass test tube to fill it to a depth of about ½ inch. Hold the test tube in an almost horizontal position; tap gently to distribute the powdered gypsum in the lower quarter of the test tube. Holding the test tube with a test-tube holder, heat the lower quarter of the tube. Observe what happens throughout the entire test tube.

3. What were your observations?

As the gypsum was heated, the particles seemed to move a little. A small amount of liquid condensed in the cool end of the tube. A small amount of vapor escaped from the test tube.

4. Examine the formula for gypsum given in Step A. How would you explain your observation in **B-3**?

During heating, water is dissociated from the gypsum.

The water condenses in the cool end of the tube.

5. Does this prove that the liquid droplets are water? Why?

No. No test was made of the properties or composition of the liquid.

6. Refer to Investigation 10-1 and use it as a reference to outline a way to test the liquid to determine whether or not it is water. How would you test the liquid?

One method is to use anhydrous copper sulfate. Remove a few droplets of the liquid from the tube by means of a glass rod and touch the liquid to the anhydrous copper sulfate. If the color changes to blue, you know that water is present.

This is a standard experiment in physics courses and in most physical science courses. We have omitted the several corrections that account for the heat transfers to the beaker, the thermometer, and the glass tubing. No provision is made for maintaining adiabatic conditions. Therefore the results will be low. To include these precautions would make the apparatus unreasonably expensive and the calculations too long. We have included just enough of the corrections to make the students realize that what appears to be a simple procedure when an investigation is described becomes complicated when all contingencies are taken into account.

Estimating the Heat of Condensation

Aim: To estimate the heat of condensation

MATERIALS
Steam generator (boiler): 600-ml Erlenmeyer flask and 2-hole stopper to fit Glass and rubber tubing Water trap: 125-ml Erlenmeyer flask and 2-hole stopper to fit Bunsen burner 250-ml beaker Water Thermometers (2) Balance and weights

All the equipment should be available in a school laboratory. The diagram shows how it is put together. A pear-shape flask may be substituted for the Erlenmeyer flask as a steam generator.

Step A Assemble the apparatus as shown in Figure 1. Fill the boiler half full of water. Place it over the Bunsen burner and light the flame. Proceed to Step B while you are heating the water in the boiler to produce steam.

Step B

Steps B–D, questions 1–20, will vary from setup to setup. The authors' experimental data is given below as a guide.

1. What is the weight of the empty, dry beaker to the nearest 0.1 g?

153.3 g

2. Fill the beaker two-thirds full of water and then weigh the beaker and water. What is its weight to the nearest 0.1 g?

338.2 g

3. Place a thermometer in the beaker of water and weigh the combination. What is the weight of the combination to the nearest 0.1 g?

374.8 g

4. What is the temperature of the water? *Be sure to leave the thermometer in the beaker of water.*

22.5 °C

5. What is the weight of the water in the beaker? (**B-2** minus **B-1**)

184.9 g

Step C When steam is flowing freely from the tube attached to the water trap, put the mouth of the tube into the beaker of water. Be sure the mouth of the tube is near the bottom of the beaker. Allow steam to flow into the beaker of water for 5 or 10 minutes.

This temperature was recorded at 6000′ above sea level.

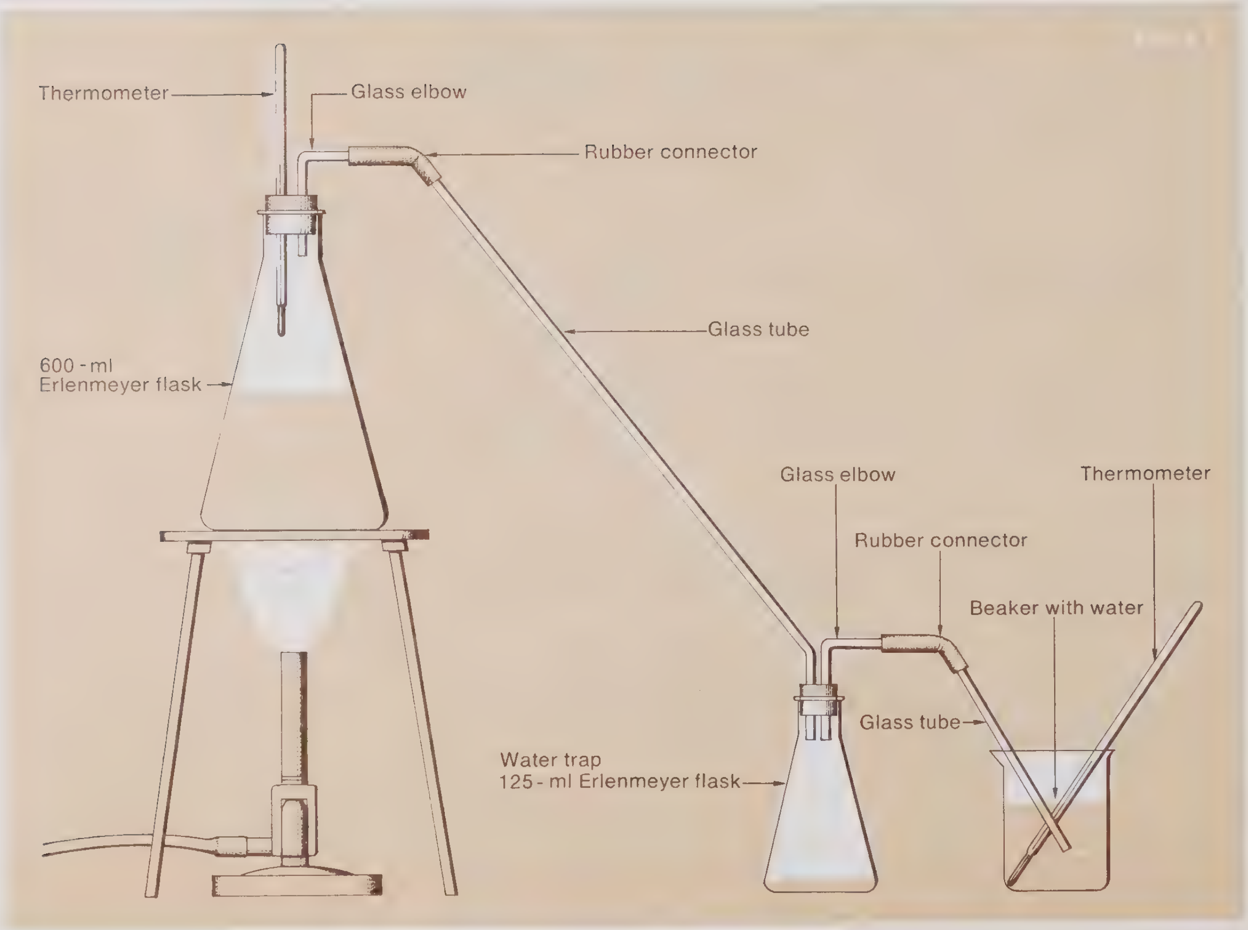
6. Read the temperature of the steam by means of the thermometer in the stopper of the boiler. What is its temperature?

94.6 °C

7. What is the temperature of the water in the beaker? (Stir the water gently to be sure it is well mixed.)

47.0 °C

8. Turn off the Bunsen burner. Disconnect the glass tube that discharged steam into the beaker of water. *Leave the tube in the beaker. Do not lose any water.*



9. Weigh the beaker, water, tube, and thermometer to the nearest 0.1 g. What is the total weight?

388.6 g

10. Remove the glass tube from the beaker of water. Dry the tube inside and out. What is its weight to the nearest 0.1 g?

6.3 g

11. Subtract the weight of the tube from the result you got in **C-9**. What is the weight of beaker, water, and thermometer?

382.3 g

12. What is the weight of the water that condensed from steam? (**C-11** minus **B-3**)

7.5 g

13. What was the weight of the water in the beaker at the beginning of the investigation? (**B-2** minus **B-1**)

184.9 g

14. What was the weight of the water in the beaker at the end of the investigation? (**C-12** plus **C-13**)

192.4 g

You now have all the data needed for further calculations.

Step D From the data you have accumulated, it is possible to trace the heat that warmed the water in the beaker.

15. What was the change in temperature of the water in the beaker? (**C-7** minus **B-4**)

24.5 °C

16. How many calories were added to the water with which you started the investigation? (**D-15** times **C-13**)

24.5°C × 184.9 g = 4530.1 cal

17. Look at **C-6** and **C-7**. What was the change intemperature that occurred for the water that condensed from the steam?

47.6 °C

18. Look at **C-12** and **D-17**. How many calories were lost by the water that was produced from steam?

7.5 g × 47.6°C = 357.0 cal

19. The heat noted in **D-18** was added to the water with which you started the investigation. What else added heat to that water?

Latent heat of condensation

20. How many calories were released by condensation of the steam? (**D-16** plus **D-18**)

4173.1 cal

Results over 450 cal are satisfactory.

21. How many calories were added to the water by one gram of condensing steam? (**D-20** divided by **C-12**)

4173.1 cal ÷ 7.5 g = 543.1 cal

The Latitude from the North Star

Aim: To determine the latitude from the North Star

MATERIALS
Cardboard
Thread
Weight (about 20 g)
Paper clip
Protractor

Readily available sources of cardboard are pad backs and the cardboards that laundries put into men's shirts. Each piece of thread should be about 18″ long.

Step A Look at Figure 1 to see how to construct your instrument. Put a pinhole in one corner of the cardboard as shown. Poke the end of thread through the hole and tie a small paper clip to the thread. Pull the thread tight, with the paper clip against the cardboard. Tie the small weight to the free end of the thread.

Step B Locate the North Star off the handle of the Little Dipper. Hold the cardboard vertically so that you can sight along the upper straight edge. Be sure that the weight is hanging free and the thread is *just* touching the flat surface of the cardboard. Sight along the straight edge toward the North Star. When the star is just on the edge of the cardboard, carefully hold the thread in place against the cardboard with your thumb and fingers.

Make at least three sightings, and use the zenith angle that is the average of the three sightings. The answers to **B-3** and **B-4** will depend upon your latitude. If possible, provide the students with a picture showing the relationship of the positions of the North Star and the Little Dipper.

1. With a pencil, make a mark on the cardboard near the lower edge where you are holding the thread.

2. With a ruler, draw a line from the mark you made, through the hole through which the thread passes, to the upper straight edge of the cardboard along which you sighted. If you were to extend this zenith line straight up into the sky, it would lead to the zenith point. The zenith angle is the angle formed between the zenith line and the sight line to the North Star.

3. With a protractor, measure the angle between the line you drew and the edge of the cardboard along which you sighted. This is equal to the actual *zenith angle* of the North Star, as shown in Figure 1. What is the zenith angle of the North Star?

______________ °

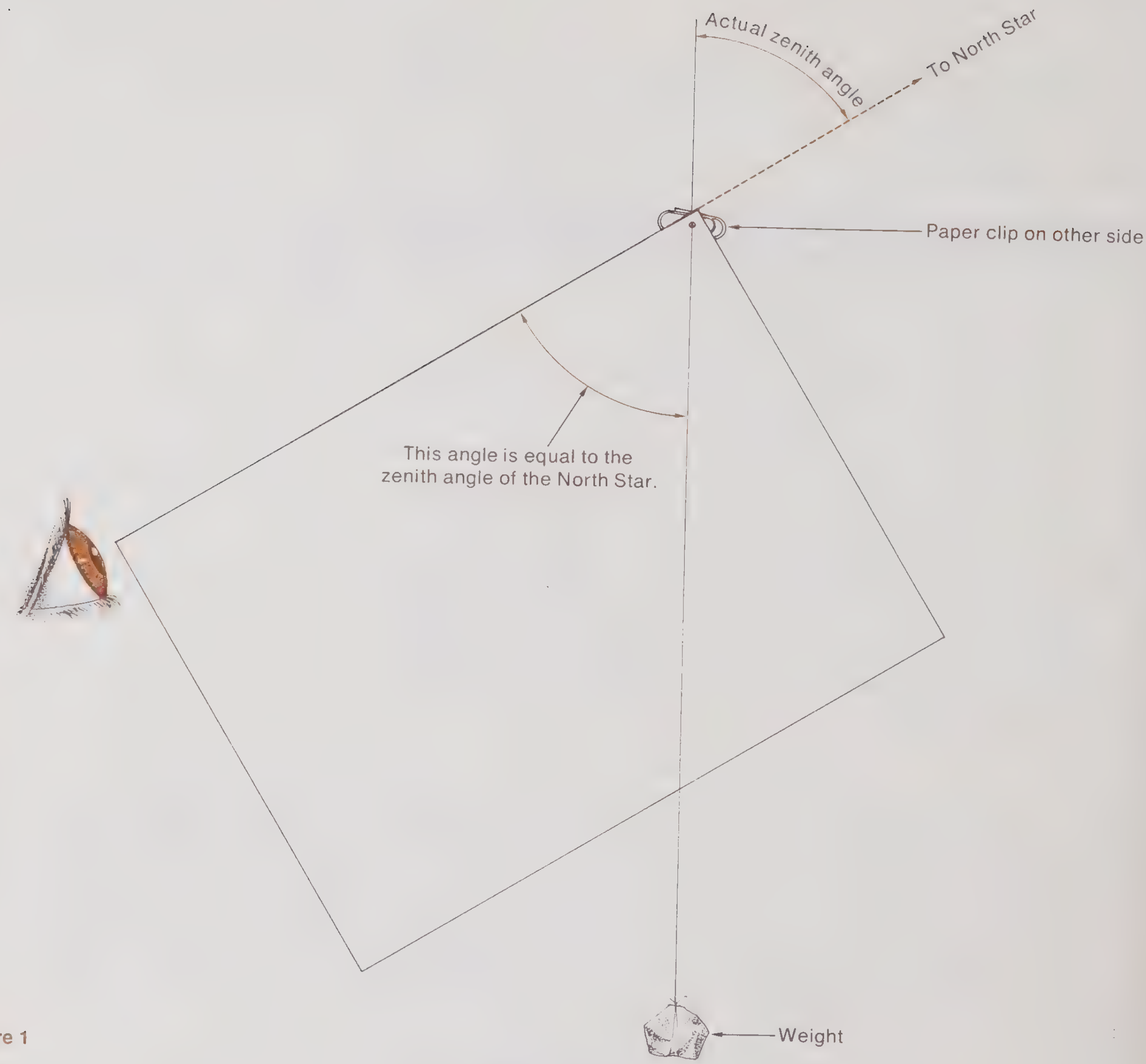


Figure 1

4. Look at Figure 2. Consider the pinhole in Figure 1 as the center of the earth in Figure 2. Consider yourself as the observer standing on the surface of the earth. The distance between you and the center of the earth is negligible, since the North Star is so far away. Therefore, you can assume that the zenith angle starts at the surface of the earth. In other words, you can now say that the zenith angle lies between the zenith line and the line from you to the North Star.

5. Now we want to find the altitude angle. This is the angle formed between the horizon and the line from you to the North Star. You can find the altitude angle once you know that the zenith line and the horizon form a 90° angle. Using this knowledge and the information in **B-3**, what is the altitude angle of the North Star?

________________ °

6. Notice in Figure 2 that the latitude angle plus the zenith angle equal 90°. How many degrees is the latitude angle?

_______________ °

The latitude is the angle between the plane of the equator and the zenith, or the difference between 90° and the zenith angle of the North Star.

The latitude angle at your school equals 90° minus the zenith angle, which the students measured with their protractors.

7. Which two angles in Figure 2 are equal?

Latitude and altitude

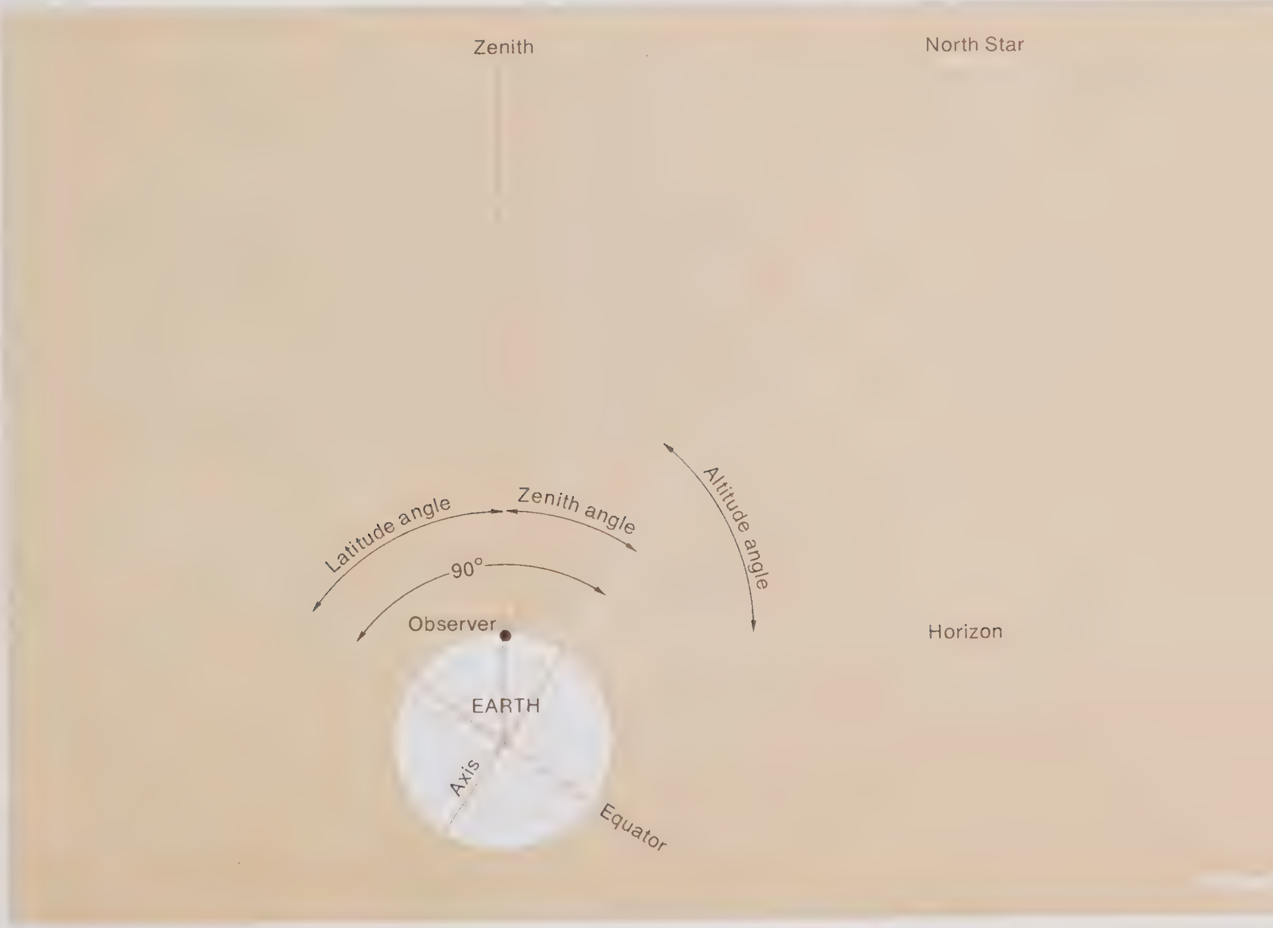
8. From a map in an atlas, determine the latitude of the place from which you made your observation.
What is the latitude indicated in the atlas?

_______________ °

9. How much error is there between the atlas latitude and your determination of the latitude?

_______________ °

The error should be not more than 2° or 3° from a single, carefully made sighting. It should be less than 1° if the average of three sightings is used to compute the zenith angle of the North Star.



10. How do you account for the error?

The most common sources of error are (1) that the weight is not hanging free and still when the thread is clamped to the cardboard with thumb and finger, (2) that the act of clamping the thread pushes the sightline off the star, and (3) inaccurate reading of the protractor.

The sun's zenith angle will vary from day to day and, of course, from hour to hour.

Step C If you want to determine the zenith angle of the sun, you should not sight directly toward it. The sun is so bright that it can damage your eyes. Instead, do it this way: Push two round-headed pins through the cardboard near the sighting edge, one at one end and the other at the other end. Point the cardboard toward the sun so that the shadows of the two pinheads fall upon each other. Hold the thread in place against the cardboard and draw the line that represents the thread. Measure the angle between that line and a line between the two pinholes made by the round-headed pins. That angle is the sun's zenith angle. From this angle, you can also determine the sun's altitude angle.

Effect of Changing the Length of an Hour

Aim: To discover what happens when the length of an hour is changed

Step A Suppose one hour were made up of 30 minutes, each minute the same length of time as the minute we use. We will call these new hours "short hours."

The hour is one of the several man-made units of time. It can be changed at will, but it would be chaotic if each nation decided to set its own length of an hour. This investigation is designed to impress upon your pupils the artificiality of the hour and the need for worldwide uniformity.

1. How many short hours would there be in a day?

48 sh hr

2. How many short hours would there be between sunrise and sunset on March 21?

24 sh hr

3. Through how many degrees does the sun appear to pass in a conventional hour?

15 °

4. Through how many degrees would the sun pass in a short hour?

7½ °

5. Washington uses 75th-meridian time and Denver uses 105th-meridian time. What is the conventional time in Denver when it is noon in Washington?

10:00 A.M.

6. What would be the short-hour time in Denver when it is noon in Washington?

20:00 A.M.

Step B Suppose we put the day on a decimal system, with 10 hours in the day. We will call these hours "deci-days." We would need no minutes because we then could use decimals of deci-days.

7. How many degrees of sky would the sun pass through in a deci-day?

36 °

8. Look back at **A-5**. What is the angular difference, as measured by the difference in degrees, between the time meridians of Washington and Denver?

30 °

9. What would be the deci-day time difference between noon at Washington and noon at Denver?

30/36 of a deci-day, or 5/6 of a deci-day, or 0.833 deci-day

10. If school started at 8:00 A.M. conventional time, at what time would it start in deci-days? Hint: Convert 8:00 A.M. to a decimal of a day.

8 hr equals 8/24 of a day, or 1/3 of a day, or 0.333 of a day, or 3.33 deci-days.

11. If school closed at 3:00 P.M. conventional time, what time would this be in deci-days? Hint: Change 3:00 P.M. to time on a 24-hour clock instead of a 12-hour clock.

15 hr equals 15/24 of a day, or 5/8 of a day, or 0.625 of a day, or 6.25 deci-days

12. How many hours and how many deci-days would school be in session?

7 hr, which is 7/24 of a day, which is 2.92 deci-days

13. How many minutes are there in a day?

1,440 min

14. How many milli-days are there in a day?

1,000 milli-days

15. How many minutes are there in a milli-day?

1.44 min

16. How many hours are there in a deci-day?

2.4 hr

17. If we adopted deci-days instead of hours, would there be any change in the length of a year? Why?

No. The year is fixed by the revolution of the earth around the sun and cannot be altered by man.

18. If we change to deci-days from hours, would there be any change in the length of a day?

No; the length of the day is fixed by the rotation of the earth.

Effect of the Sun's Angle on Insolation

Aim: To discover the effect of the sun's angle on insolation

MATERIALS
Ruler with a millimeter scale Protractor

This pencil-and-paper investigation can be used in class or assigned for homework.

Step A The parallel lines drawn in the margin of this step are exactly 1 cm apart. Let the upper line represent the horizontal ground. With a protractor, erect two parallel lines exactly 1 cm apart at 90° to the horizontal ground line. Extend these lines across both parallel lines. Shade the square that is formed. This represents the area covered by a sunray with a cross section of 1 cm² as it strikes the ground at the Tropic of Cancer at noon on June 21.

1. What is the area of horizontal ground struck by the sunray?

1 cm²

Step B On December 21 the sun at noon is 47° south of the zenith at the Tropic of Cancer. Using the two parallel lines spaced exactly 1 cm apart, construct the area covered by a sunray whose cross section is 1 cm² when it strikes horizontal ground at the Tropic of Cancer.

2. What is the angle between the sun and the horizon at the Tropic of Cancer at noon on December 21?

43 °

3. What is the area of horizontal ground covered by a sunray whose cross section is 1 cm² on December 21 at the Tropic of Cancer?

1.46 cm²

4. On June 21, 1 cm² of horizontal ground at the Tropic of Cancer receives the maximum insolation if the day is clear. Call this 100%. What percent of maximum insolation is received by the same ground on December 21?

1.00/1.46 = 0.68 %

Step C Calculate the percent of maximum insolation that could be incident at noon on June 21 at the latitude of your school. By answering the following questions before you solve this problem, you will have all the information you need.

5. What is the latitude of your school to the nearest full degree?

(Answer will vary from school to school.) °

6. At what latitude is the sun at the zenith at noon on June 21?

23½°N latitude °

7. What is the difference in latitude between your school and the sun's position at zenith on June 21?

(Your latitude minus 23½°) °

8. How many degrees south of the zenith will the sun be at your school on June 21?

(Your latitude minus 23½°) °

Now go ahead with your diagram on the two parallel lines in the margin.

9. What area will be covered by a sunray 1 cm^2 in cross section at your latitude on June 21?

(Answer will depend upon your latitude.) cm^2

10. What percent of maximum insolation will you receive?

(Answer will depend upon your latitude.) %

Effect of the Tilt of the Earth's Axis on the Geographic Zones

Aim: To discover the effect of the tilt of the earth's axis on the geographic zones

This investigation may be used in class or assigned for homework.

MATERIALS
Ruler 90° triangle, or 3″ x 5″ card Protractor

Step A In Figure 1, you will find a circle that represents the earth and a line through it that represents the axis tilted 23½°. The vertical line to the left represents the surface of the sun. Place the triangle so that one edge is on the line that represents the sun's surface and the side at a right angle to that edge is tangent to the earth circle at the north. Put a dot on the earth circle at that point. Do the same at the south polar end. Draw lines across the earth circle perpendicular to the axis line and through each of these dots.

Figure 1

1. What are the names of the lines you have drawn?

The Arctic Circle and the Antarctic Circle

Step B Continuing on the same figure, draw a line perpendicular to the sun's surface line and through the center of the earth circle, where the equator and the axis cross. From the points where this line intersects the earth circle, draw lines across it that are perpendicular to the axis line.

2. What are the names of these lines?

The Tropic of Cancer and the Tropic of Capricorn

3. Label the geographic zones bounded by the lines.

From north to south: North Polar (or Arctic) Zone, North Temperate Zone, Tropical Zone, South Temperate Zone, South Polar Zone

Figure 2

Step C On the earth circle in Figure 2, the axis is tilted only 10°. In the same way that you performed Steps A and B, draw in the Arctic and Antarctic circles and the Tropics of Cancer and Capricorn.

4. What changes have taken place in the extent of the geographic zones?

The Tropical Zone and the Polar Zones are narrowed and the Temperate Zones are widened.

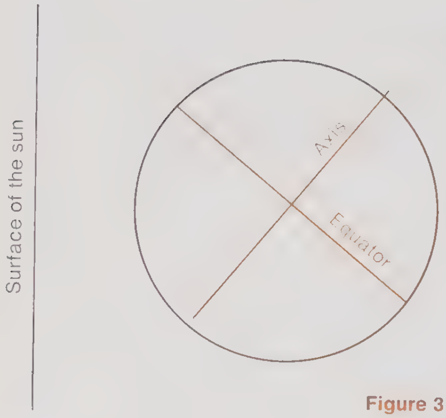


Figure 3

Step D On the earth circle in Figure 3, the axis line is tilted 40°. Draw in the boundaries of the geographic zones, using the method you learned in Steps A and B.

5. What changes have taken place in the extent of the zones?

The Tropical Zone and Polar Zones are widened and the Temperate Zones narrowed.

Step E On the basis of what you observed in Steps C and D, answer the following questions.

6. If the axis of the earth had no tilt at all, what would be the extent of the geographic zones?

The Tropical Zone would be restricted to the line of the equator, and the Polar Zones would be reduced to the points at the ends of the axis. The rest of the world would be Temperate Zones.

7. If the axis of the earth were tilted 45°, what would be the extent of the geographic zones?

The Temperate Zones would disappear and the Tropics of Cancer and Capricorn and the Arctic and Antarctic circles would be represented by the same lines.

8. What would be the situation if the earth's axis were tilted more than 45°?

There would be no Temperate Zones and the Tropical Zone and Polar Zones would overlap!

9. Prove your answer to **E-8** with a diagram.

Effect of Color on Absorption of Insolation

Aim: To discover the effect of color upon absorption of insolation

MATERIALS
Piece of grooved Styrofoam Different-colored swatches of the same material, preferably closely woven cotton or wool, *not* nylon (5) Thermometers (5) Straight pins

A piece of scrap Styrofoam about 12″ x 3″ and at least 1″ thick can be found wherever fragile equipment is shipped or received. The Styrofoam should be scored with grooves across the 3″ dimension. The grooves should be about 2″ apart and deep enough to accommodate the bulb and shaft of the thermometer.

The swatches of cloth need not be more than 1″ square. Less than 5 swatches will suffice if necessary. Use tightly woven material of the same quality and texture for each color. Use black, white, and two or three colors, such as red, blue, and green. Do not select colors so dark that they approach black. Avoid using nylon because it is transparent to infrared.

Ordinary straight pins are satisfactory; short pins are best.

Step A Place the thermometers in the grooves in the Styrofoam block. Pin a different-colored cloth over each thermometer. Place the apparatus in direct sunlight.

Lay a thermometer in each groove. Pin a swatch of material tautly over each thermometer. Be sure the grooves are deep enough so the cloth does not quite touch the bulb.

Set the apparatus in the sunshine, propped up so that the sun's rays fall as nearly perpendicular to the surface as possible.

1. After 5 or 10 minutes, read the temperature of each thermometer and record the information in the table below.

With the sun near the zenith, 5 min exposure is sufficient; otherwise, wait 10 min or longer.

Swatch No.	Color	Temperature
1	________	________°C
2	________	________°C
3	________	________°C
4	________	________°C
5	________	________°C

The temperatures recorded will depend upon several variables in addition to the color of the cloth.

Step B Examine the data you have accumulated.

2. Under which color cloth was the temperature highest?

   Black

3. Under which color cloth was the temperature lowest?

   White

4. What use do we make of the facts that you discovered?

We usually wear dark clothes in winter and in cold regions, and light clothes in summer and in warm regions.

Precise measurement of insolation is a difficult task and requires very carefully constructed apparatus. The equipment and procedures used in this investigation are simple. The resultant measurement is a good first approximation of insolation at the surface of the earth.

Measurement of the Sun's Energy

Aim: To measure energy received from the sun

MATERIALS
Special black calorimeter can
1-hole rubber stopper, No. 11
Thermometer
Watch
Water
Balance and weights

A standard calorimeter may be used provided its surface is blackened. An inexpensive calorimeter may be made by using a 6-ounce frozen-fruit-juice can. The outside of such a can should be painted with matte black to reduce reflection to a minimum. A slightly more accurate instrument can be made according to the working drawings included in these instructions. Some increase in accuracy may be gained with any calorimeter by shielding it from breezes. To do this, place the instrument in a box made of the thinnest possible plastic, such as Saran Wrap. Care must be taken to prevent shadows from falling on the instrument.

Step A Heat is measured in calories. The most convenient way to measure calories is to record the change in the temperature of water as it absorbs heat. To perform this experiment, you will measure the change in temperature of a weighed amount of water.

1. How would you define a calorie?

   A calorie is the amount of heat necessary to raise the temperature of 1 g of water 1°C.

The authors used a standard laboratory mercury thermometer. If you do not have such in your equipment, it can be borrowed from the chemistry or physics laboratory.
Any kind of watch or classroom wall clock is satisfactory for timing.
Any of the common laboratory balances of the Harvard trip balance or Ohaus type is satisfactory for weighing.

2. If the temperature of 150 grams of water increased 3°C, how many calories were absorbed by the water?

   150 g × 3°C = 450 cal

Step B *Carefully* insert the thermometer through the hole in the rubber stopper. Moisten the inside of the hole and the thermometer. Gently insert the thermometer and twist it as you gently press it into the hole.

The thermometer can be inserted more easily in the rubber stopper if both are moistened with a mixture of equal parts of water and glycerine. If glycerine is not available, plain water is satisfactory. It may be better for the teacher to insert the thermometers. This will avoid breakage by careless students. The thermometers should be withdrawn from the stoppers immediately after each experiment. Otherwise they may "freeze" in place and be very difficult to remove.
For the best results, use water that is at air temperature. Let the water stand for at least an hour before the laboratory session begins.

3. What is the weight of the calorimeter, stopper, and thermometer to the nearest 0.1 g?

   ______ g

The calorimeter, thermometer, and stopper should be dry when weighed.

4. Fill the calorimeter with water to ½ inch from the top and firmly insert the stopper and thermometer. What is the weight of this apparatus?

   ______ g

The outside of the apparatus must be dry for this weighing.

The weight of the water used in a 6-oz frozen-fruit-juice can will be 150–160 g.

5. By substracting the weight recorded in **B-3** from that in **B-4**, determine the weight of the water in the calorimeter.

B-4 ________________g

B-3 ________________g

Weight of water used ________________g

Step C You are now ready to perform the investigation. Select a place to put the calorimeter where the sun will shine directly upon it.

The answers to these will vary from student to student within a reasonably small range. They will depend upon so many factors that we cannot give you a rough estimate of what they should be.

6. Read the temperature of the water *before* placing the calorimeter in the sunshine. What is its temperature?

________________°C

7. Place the calorimeter in the sunshine and note on the line below the time when you do this.

________________hr ________________min

8. After 10 minutes, read the temperature of the water again. What is its temperature?

________________°C

9. After 10 more minutes, read the temperature of the water again. What is its temperature?

________________°C

While your students are doing these calculations, withdraw the thermometers from the stoppers.

The change in 20 minutes should be about twice that of 10 minutes.

Step D Return your calorimeter to the laboratory.

10. Can you determine by calculating in the chart below the change in the temperature of the water from the data in **C-6**, **C-8**, and **C-9**?

Change in 10 minutes	Change in 20 minutes
C-8 ________________°C	**C-9** ________________°C
C-6 ________________°C	**C-6** ________________°C
Change ________________°C	Change ________________°C

11. From the data in **B-5** and **D-10**, can you determine by

calculating in the table below the number of calories absorbed by the water in 10 and 20 minutes?

10 minutes	20 minutes
B-5 ______ g	B-5 ______ g
D-10 ______ °C	D-10 ______ °C
______	______
Calories ______	Calories ______

The two answers should be quite close.

Step E Study the data that you have accumulated.

12. Can you calculate the number of calories of heat absorbed by the water per minute? Use each of the two time periods you observed.

The three answers should be quite close and about 0.7 times the mass of water used.

Calories per minute, 1st 10 minutes ______cal

Calories per minute, 2nd 10 minutes ______cal

Calories per minute, 20 minutes ______cal

13. Why are the three answers in **E-12** slightly different from each other?

Possible answers include the following: during the investigation the sun's angle in respect to the calorimeter changed; the cloudiness of the sky changed; the timing was not absolutely accurate; or the reading of the temperature was not absolutely accurate.

A frozen-fruit-juice (calorimeter) can measures 9.7 cm tall and 5.3 cm in diameter. Its vertical cross section is approximately 51.4 cm^2. The experimental cross section depends upon the amount of water in the can. It will be from 40 to 44 cm^2. This is only a rough approximation for this investigation. Since the can is a cylinder, the sun's rays meet it perpendicularly only along a line. The effective cross section is difficult to calculate. The difference between the experimental and effective cross section is the largest error in the investigation. See if any of your students recognize this.

NO. 15—

This will vary with latitude, date, time of day, condition of the atmosphere, and such items as reflection from nearby buildings. It may vary all the way from 0.4 to 0.9, and very rarely it will be as high as 1.0 ly/min.

14. Can you calculate the cross section of the calorimeter exposed to the sun? Use the metric system and calculate as accurately as you can.

______________ cm^2

15. Calculate the langleys, which are the calories per cm^2, that are received per minute by your calorimeter. How many langleys are received per minute?

______________ ly/min

16. It is estimated that 1.4 ly/min are received at the surface of the earth from the sun, when the sun is directly overhead. Why is your answer to **E-15** lower than this?

Answers include the following: the sun was not directly overhead; the condition of the atmosphere; local reflection; radiation from the calorimeter; observational errors; improper estimate of effective surface because of the shape of the calorimeter.

The Cape Cod barometer works because the air captured in the bottle cannot change its mass. Therefore, as the atmospheric pressure changes, the volume of air in the bottle changes. The volume increases with lowered pressure and decreases with increased pressure. The atmospheric pressure is transmitted to the captured air by the water in the bent tube.

INVESTIGATION 14-1

Making a Cape Cod Barometer

Aim: To make a simple barometer

MATERIALS

- Empty bottle
- 1-hole rubber stopper
- Piece of glass tubing, 12″ long; or 1 piece 2″ long, 1 piece 8″ long, and 1 piece of rubber tubing 6″ long
- Water
- Ink or food coloring

Any kind of bottle for which you can get a 1-hole rubber stopper may be used: soft-drink bottles, pint medicine bottles, or quart fruit-juice bottles. The single, bent-glass tube works better than the combination of glass tubing and rubber tubing. However, it is more difficult for ninth graders to make the single tube.

If the tube is made by bending a single 12″ piece of glass tubing, tell the students to be careful not to burn themselves on the hot glass. Instruct them to test the bent area by cautiously bringing it toward one cheek. If they can feel the heat before the glass touches their skin, the tube is too hot to hold for the second bend. If the tube is assembled from glass and rubber tubing, tight and permanent joints can be made by putting a little shellac on the glass tubing. The rubber tubing should be thick-walled but need not be pressure tubing.

Step A A barometer like the one you will build is shown in Figure 1. The first step is to make the bent tube. You can use a single piece of glass tubing and make two bends in it. One bend should be about 2 inches from one end, and the other bend should be far enough away from the first so that the upright tube is clear of the bottle, as shown in the diagram. Another way to make the bent tube is to use two pieces of glass tubing and join them with a piece of rubber tubing.

Step B Insert an arm of the bent tube in the rubber stopper as shown in Figure 1. Wet both the glass and the hole in the stopper. Be careful not to break the glass and cut yourself!

Whenever glass tubing is inserted in a rubber stopper, both the tube and the stopper must be lubricated. Plain water is satisfactory. Water with a little glycerine in it is better.

Step C To make the Cape Cod barometer, half-fill the bottle with water. Add enough ink or food coloring to stain the water. Insert the rubber stopper firmly in the mouth of the bottle. Invert the whole apparatus. Water will flow into the bent tube. Hang the apparatus on the wall where it will not be disturbed. If you have used the kind of bent tube made with rubber tubing, fasten the long piece of glass tube to the bottle with a strong rubber band.

The water should be stained dark enough to be easily visible in the glass tubing. It might be well to anchor the rubber stopper to the bottle with light wire or sealing wax. A hanger for the bottle can be made from bent wire or strong cord. Caution must be taken to prevent the inverted bottle from swinging once it is hung up.

Step D Fasten a scale beside the upright glass tube, with the water level in the tube at about the middle of the scale. Record the position of the upper level of the water in the glass tube in the table at the end of the investigation. Each day, record in your table, the level of the water.

The scale may be a plastic ruler graduated in 1/16-inch intervals or in millimeters. It may be a paper millimeter scale such as the kind used frequently in physics labs.

NOTE:

Extreme changes in temperature will affect the level of the water in the upright tube by changing the volume of air in the bottle.

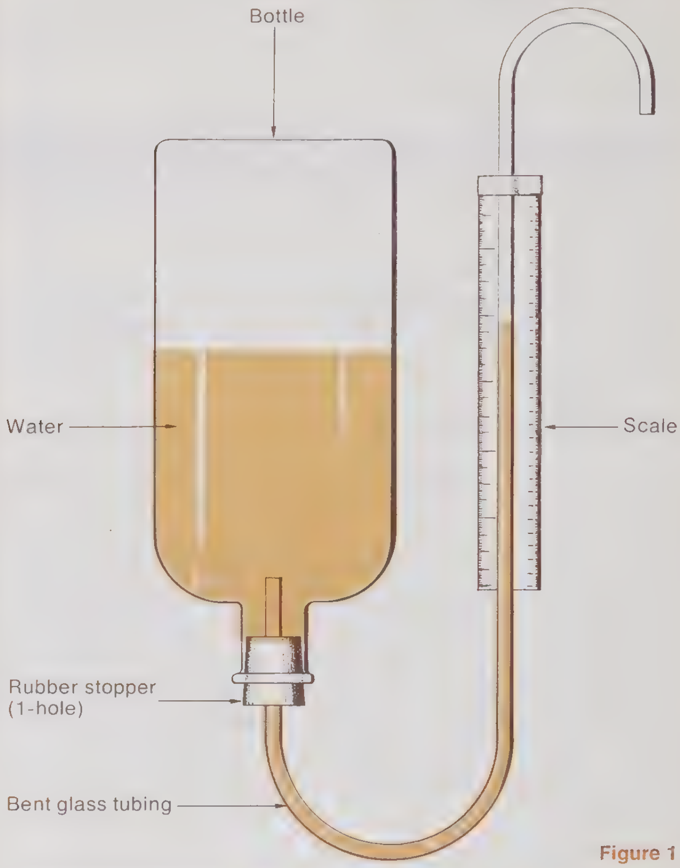


Figure 1

Step E

1. Does the level of the water in the upright tube stay at the same point on the scale from day to day?

(The usual answer is No. Upon rare occasions it may be Yes.)

2. Why does the water level in the upright tube vary?

It varies because the air pressure varies and the air trapped in the bottle expands and contracts.

3. What causes the water to rise in the upright tube?

A decrease in air pressure causes the air in the bottle to expand and the water in the tube to rise.

4. What causes the water level to drop in the upright tube?

An increase in air pressure reduces the volume in the bottle and causes the water level to drop in the tube.

Step F Find the weather reports in the newspapers for the days you observed your own apparatus. Enter the atmospheric pressure for those days in the proper places in your record table.

5. Did your apparatus show the same directions of change in atmospheric pressure that were recorded at the weather station?

Yes

Step G Plot a graph on the next page that compares your readings of your barometer scale with the pressures recorded by the weather station. From this graph, estimate the readings you should find on your scale that would be comparable to the atmospheric pressures at sea level given below. How do the readings on your barometer compare with those of the weather station?

Atmospheric pressure at sea level	Cape Cod barometer scale
30.5 in	
30.0 in	
29.5 in	

STEP F—
It is wise to clip the weather report data for a week or so following the investigation and post these clippings on the bulletin board.
The answer should be Yes, but if the reporting station is more than 10 miles away, the variations may not be parallel on all days. This is especially true in mountainous country.

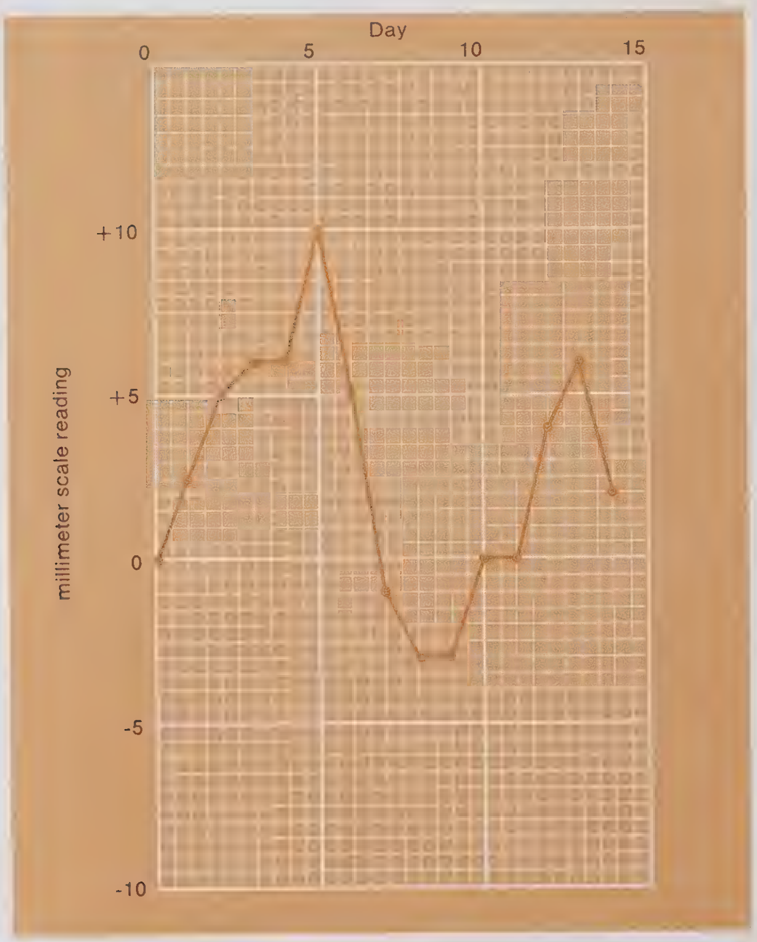
STEP G—

Suggest to your students that they first plot the weather station data with calibration of the graph along the left edge in inches of air pressure. Then, using about the same line as the atmospheric pressure on the first day for the first reading of the Cape Cod scale, label the lines at the right edge with the Cape Cod scale.
The information in the following table and in the graph is from the authors' test of the investigation. The amount of variation depends upon atmospheric pressure, the volume of air trapped in the bottle, and the inner diameter of the glass tube.

TABLE

Day	Reading in mm
0	0
1	+3
2	+5
3	+6
4	+6
5	+10
6	+5
7	−1
8	−3
9	−3
10	0
11	0
12	+4
13	+6
14	+2

TABLE		
Day	Your Readings in mm	Weather Bureau Readings
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		



Making a Wind Gauge

Aim: To make a simple wind gauge

MATERIALS
4″ squares of heavy chipboard, ⅛-inch plywood, light-gauge aluminum, or galvanized iron (2)
Piece of wood, ½″ x 1″ x 15″
Piece of wood, ½″ x 1″ x 12″
Machine bolts and nuts, ¼″ x 1½″ (2)
Washers to fit the bolts (6)
Bolts, ⅛″ x 1½″, with nuts and washers (2)
Bolts, ⅛″ x 1″, with nuts and washers (2)

Step A Examine Figure 1 and assemble the wind gauge apparatus as follows: Attach the scale (one of the 4″ squares) to the support arm. If you wish, you may cut the scale to make a quarter-circle, as shown in Figure 1. Make the wind paddle by bolting the other 4″ square to the swinging arm as shown. Attach the wind paddle to the support arm. Do not tighten the bolt holding the paddle. The paddle must be able to swing freely when you blow against it.

Step B Once the wind gauge is assembled, it must be calibrated. This can be done by comparing it with a standard anemometer or wind gauge. To do this, place the wind gauge you have made near the standard instrument and mark a line on the scale of your gauge along the front edge of the paddle. Read the standard instrument and number the line you have just drawn. Repeat this several times with winds of different velocities. This method is slow because you cannot govern the wind. It will take several days to develop a scale. A faster method is to use an automobile. Select a day when there is little or no wind. Hold your wind gauge out of the window and ask the driver to keep the speed constant at 10 mph, 20 mph, and 30 mph. Mark the deflection of your gauge on the scale for each of these speeds.

Step C The next task is to complete the scale for your wind gauge. To do this, you must have three known points in addition to zero. Zero is when the paddle is hanging in still air in a room. From the known points – 10 mph, 20 mph, and 30 mph – estimate where the intermediate points should

This is a job for the student who is handy in the shop and for the industrial arts teacher. The diagram and list of materials are all that are needed to construct the apparatus.
The equation for exertion of force is

$$f = \frac{mv^2}{2}.$$

Air at 6,000 feet is less dense (m is lower); therefore, with equal v, f will be smaller.
All wind-velocity measuring devices depend upon the equation in the note for **E-1**. Therefore, since mass of air per unit volume decreases with altitude, altitude will affect the accuracy of all such instruments.

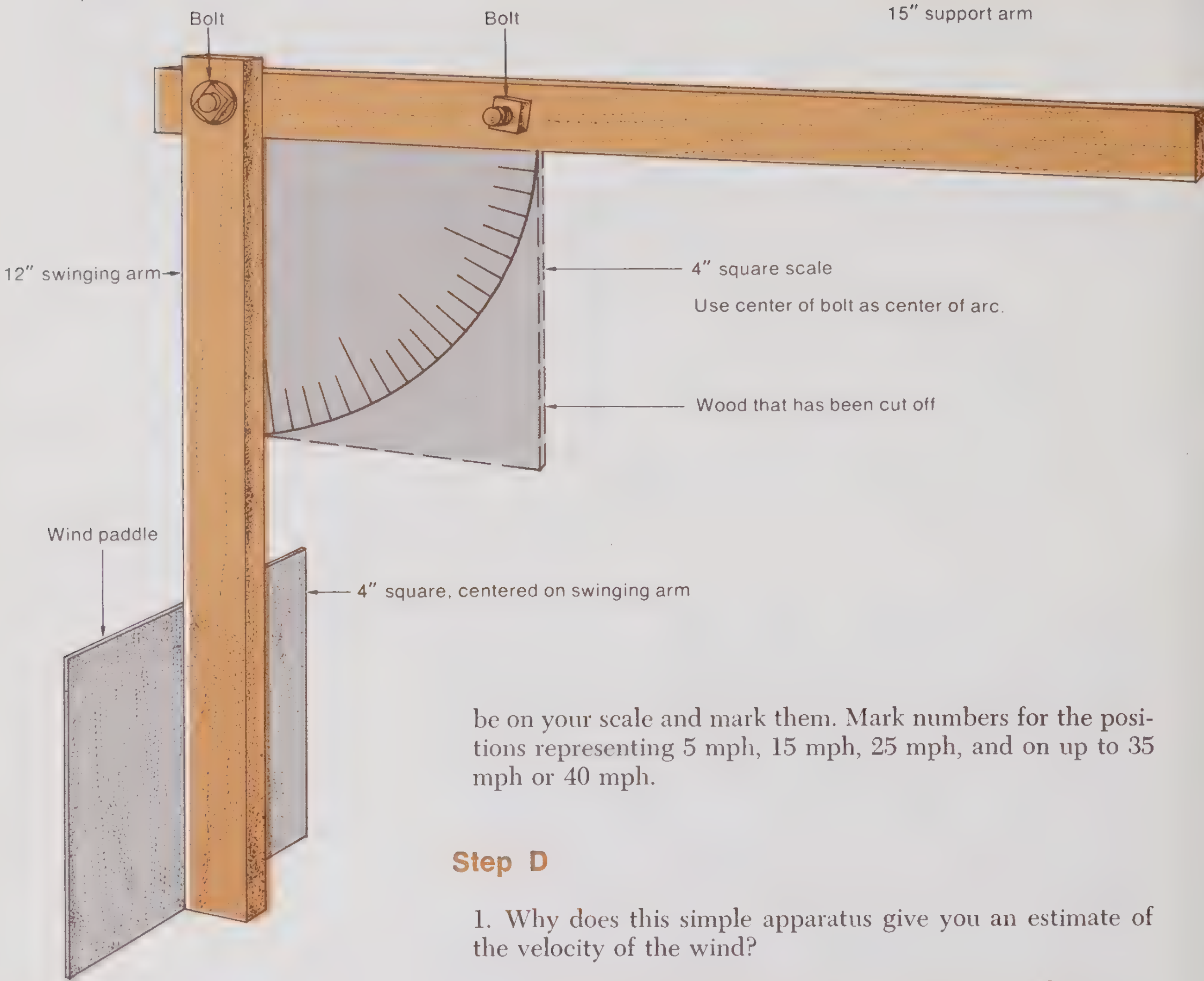


Figure 1

be on your scale and mark them. Mark numbers for the positions representing 5 mph, 15 mph, 25 mph, and on up to 35 mph or 40 mph.

Step D

1. Why does this simple apparatus give you an estimate of the velocity of the wind?

Air has mass; therefore, as it moves, it exerts force.

2. Why does your apparatus give you only an estimate of the wind velocity?

Because of friction within the apparatus and the crude calibration of the scale

3. If you calibrated your instrument at sea level, would your instrument read high, or low, when you used it in the mountains at 6,000 feet?

Low

4. Why does altitude affect the accuracy of the reading of any wind-velocity measuring device?

Because the mass of air per unit volume decreases as the altitude increases.

The data was produced by a polar outbreak in midwinter. You will need a pad of 8½″ x 11″ tracing paper for this investigation. This can be purchased in any good stationery store. If your school teaches mechanical drawing, it probably carries this paper in stock. You should have a few well-sharpened No. 2 pencils on hand for students who do not have them.

Making a Weather Map

Neatness is paramount in this investigation. Blunt pencils must be sharpened. It will take from 45 minutes to an hour for your class to complete Step A. It should be done under your close supervision and with your help when needed. To reduce clutter, only the last two numbers of the pressure in millibars need be recorded on the overlay. There will be no repetition, since the range extends from 1042 to 998. In **A-2** many of your students may have difficulty at first interpolating the lines. A demonstration on the chalkboard before anyone starts on **A-2** will be helpful.

Aim: To prepare a weather map from data

Table I includes part of the data collected at 8 A.M. on January 15 at weather stations east of the Rocky Mountains in the United States and southern Canada.

Step A Lay a piece of tracing paper over the map in Figure 1. Clearly mark on the tracing paper (the overlay) three of the corners of the map. You can now precisely replace the overlay if it happens to move. Try not to let it move. The marks you made are called register marks.

TABLE I

Station	Temp. (°F)	Pressure (mc)	Wind Direction	Sky	Station	Temp. (°F)	Pressure (mc)	Wind Direction	Sky
1	−18	1040	NNW	oc	28	25	1011	SW	pt c
2	−25	1042	NNW	cl	29	18	1014	SW	s
3	−23	1034	NNW	pt c	30	10	1023	W	cl
4	−4	1019	NE	cl	31	2	1026	W	cl
5	−10	1014	NW	oc	32	2	1027	NW	s
6	0	1005	NW	oc	33	−6	1017	NE	oc
7	30	998	W	oc	34	8	1023	NE	oc
8	19	1010	SSE	oc	35	20	1023	NW	oc
9	28	1010	SSE	oc	36	22	1024	NW	cl
10	33	1002	SSW	oc	37	25	1017	N	oc
11	25	1002	SW	oc	38	41	1016	NE	oc
12	23	1004	WSW	r	39	42	1015	NE	c
13	21	1004	W	s	40	28	1016	W	c
14	14	1011	NW	oc	41	47	1012	W	c
15	−1	1058	NW	oc	42	49	1010	NW	c
16	−8	1033	NW	s	43	51	1012	WSW	r
17	−15	1037	N	pt c	44	62	1013	SW	c
18	0	1029	N	c	45	60	1012	SSE	c
19	−15	1027	N	c	46	65	1012	S	c
20	10	1026	W	cl	47	61	1011	NW	r
21	9	1019	W	cl	48	67	1011	S	r
22	13	1011	W	s	49	51	1012	N	c
23	38	1006	W	c	50	58	1012	SW	r
24	40	1007	SSE	c	51	50	1013	N	c
25	40	1008	NW	c	52	70	1015	S	pt c
26	47	1009	E	r	53	75	1016	S	cl
27	39	1011	W	c					

c – cloudy pt c – partly cloudy cl – clear r – rain s – snow oc – overcast

1. Start with station 1, in the northwestern corner of the map. Put the tip of a very sharply pointed pencil in the center of the circle near the number. Draw a short line, not longer than 1/8 inch, from the center of the circle in the direction the wind is blowing according to the data given for the station in Table I. Put the barbs of an arrow at the end of the line you drew. Close to the station circle, write in small print the *last two numbers* of the atmospheric pressure recorded in the table for the station. Repeat this process for each of the 53 stations in the table. You will always find the next number near the last one you used.

2. Again starting in the northwestern corner, draw in the isobars – lines connecting points of the same atmospheric pressure – at each 5-millibar interval. For example: 1040 mb, 1035 mb, 1030 mb, to 1000 mb, the lowest one represented. You will immediately discover that very few stations had pressures in even 5 millibars. Therefore, you will have to decide from all the stations in a small area where to draw the lines between stations. For example: the 1040-mb line will pass a little closer to the station with pressure 1042 than to the one directly south of it, where the pressure was 1037. Most of the lines will run off your map. Label each line with its pressure value at both ends where the line goes off the map. Only two or three of the isobars will close. For these, leave a break in your line for the label.

Everyone should recognize the one high in the northwestern corner, and the one low in the northeastern corner. Some of your better students may recognize that there is a shallow trough over the southern Appalachians.

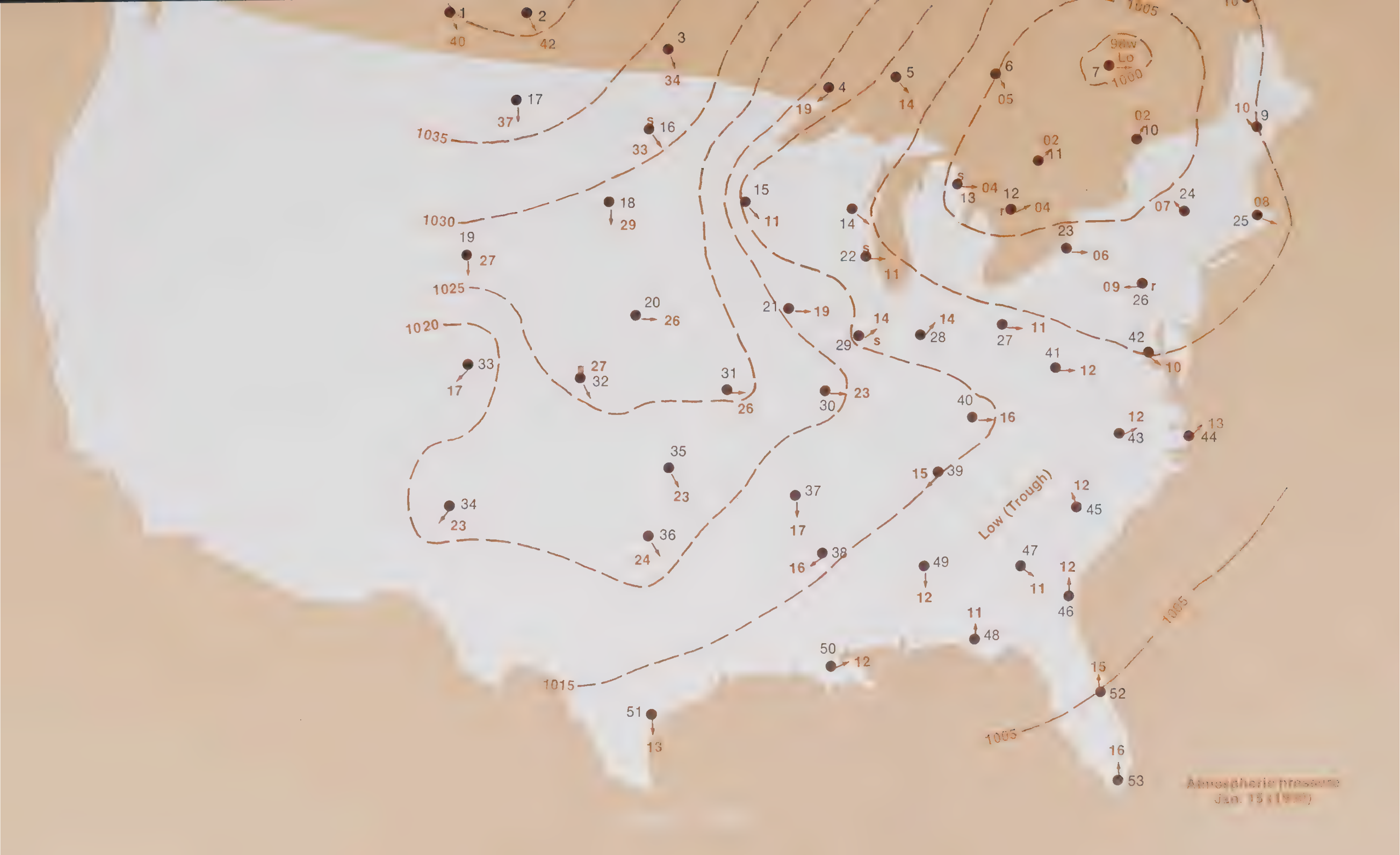
3. Study the pattern of the isobars. Label any lows and highs that you believe existed. Use both the isobars and the wind arrows to help you make your decisions.

4. At which station (or stations) do you think the strongest winds were recorded?

Station 15, where the isobars are closest

5. At which station (or stations) do you think there were only light winds?

Light winds probably blew at Station 20. Stations 7, 10, and 11 also may have had very light winds.



1035
1030
1025
1020
1015
1005
1000
Lo
Low (Trough)
Atmospheric pressure

6. Remember that this is a record for January. In what way does the arrangement of isobars suggest that a polar outbreak has occurred?

The southward elongation of the high indicates that a polar outbreak has occurred.

This part of the investigation can be assigned as homework or used in a second class period. It takes a little less time to do than Step A.

Step B To test your answer to **A-6**, it will be necessary to prepare a map of the isotherms, lines that connect places that have the same temperature readings. Use a second sheet of tracing paper as an overlay. Register it at the same corners you used in Step A.

7. Put a dot in each of the station circles as you enter the temperature recorded in the table for that station. Make your numbers clear but small. Use a very sharp pencil. Start in the northwestern corner, as you did in Step A.

8. Draw in the isotherms, using the same technique you used for the isobars.

9. Place your overlay for temperature over the one for pressure, using the register marks. Does the distribution of temperatures support your answer for **A-6**? In which region is this particularly evident.

The pattern of isotherms supports the hypothesis that a polar outbreak occurred, especially in the lower Mississippi Valley.

Step C Here are tables of 8 A.M., EST, temperatures for several groups of stations.

This step is inserted to reinforce the idea of a cold front moving southward. It may be omitted if time does not allow its completion, or it may be assigned as homework after Steps A and B have been completed.

TABLE II

	Great Plains		Eastern Midwest		Opposite sides of Appalachian Mts.	
	Station		Station		Station	
	32	35	28	40	23	26
Jan. 14	10	33	40	53	43	45
Jan. 15	02	20	25	28	38	47
Jan. 16	−10	10	20	33	20	30

10. Station 32 is not far north of 35, Station 28 is not far north of 40, Station 23 is west of the mountains and 26 east of them. On which date did the cold front reach each station?

Station 32 Jan. 14 or earlier 35 Jan. 15

28 Jan. 15 40 Jan. 15

23 Jan. 15-16 26 Jan. 16

11. In what direction was the front moving?

The front was moving southward and then veered to the northeast.

12. Did the Appalachian Mountains act as a barrier to the movement of the cP air?

Possibly the Appalachians temporarily confined the cold air to the west of the range.

TABLE III

	Gulf Coast			Atlantic Coast		
	Station			Station		
	50	51	48	25	44	52
Jan. 14	63	62	69	40	65	68
Jan. 15	58	50	67	40	62	70
Jan. 16	40	31	50	39	50	65

13. On what day did the front reach the Gulf Coast?

The front began to enter the Gulf Coast area, reaching New Orleans on Jan. 15. It was well established by Jan. 16.

14. Does this support your answer to **A-6**? Why?

Yes. There is evidence of cold temperatures advancing progressively southward over the three days.

15. Was the effect of the front as severe on the Atlantic Coast as on the Gulf Coast and in the Midwest? Why?

The effect was not so acute on the Atlantic Coast as in the Midwest and Gulf Coast area. The greatest drop in the southeast along the coast was 15°, and freezing was not approached. On the Gulf Coast, drops of over 17° were minimal and freezing occurred. The Appalachians may have acted as a partial barrier. More likely, the trough over them sucked mild ocean air into the Atlantic coastal regions.

Keeping a Weather Record

Aim: To prepare and keep a weather record

Before scientists invented the various instruments that are used to measure features of the weather, many people kept long and accurate accounts of local weather for their community. You can do this, too. Although weather instruments are nice to have, you do not need any to keep such a record. What you do have to do is observe accurately and record your observations faithfully. These observations should be made at the same time each day – while walking to school in the morning or while waiting for the school bus. These are the features you should observe and record:

1. Is the temperature hot, warm, cool, cold, or below freezing?

2. How much of the sky is covered with clouds?

3. From which direction is the wind blowing?

4. How strong is the wind? For this, use the U. S. Weather Bureau terms:

Calm – no wind at all.

Light – leaves flutter and you can feel wind on your face.

Gentle – leaves and twigs on trees move; flags flap.

Moderate – raises dust and loose paper.

Strong – you have some difficulty walking and have to lean into the wind.

Gale – you don't go out! Trees sway. Small twigs break from trees.

---

5. Is there no precipitation, or is there fog, drizzle, rain, heavy rain, snow, sleet, hail, or thunderstorms?

The observations you make should be written down in the table on the next page.

This investigation can be performed anywhere, but it is more successful in rural and suburban areas than in the heart of a city, where items 2, 3, and 4 cannot be observed accurately. The canyonlike streets cause erroneous impressions of the strength and direction of the winds; it is difficult to see enough of the sky to estimate sky cover; and smog also may interfere. What is observed in a city street is a microclimate, highly modified by the paving, the buildings, and the heat escaping from these structures.

A five-minute daily comparison and discussion of the observations by different students will demonstrate that making objective records with which all will agree is a difficult task. It should be explained in these discussions that no one's observations are really wrong or right. They are highly subjective, personal opinions.

If your locality has a reporting weather station, have your students compare their subjective observations with the objective observations reported by the station. If your locality does not have such a station, have your students try to find a pattern of differences between the weather at your locality and that of a reporting station.

Date	Temperature	Sky	Wind direction	Wind strength	Precipitation	Other notes

INVESTIGATION 17-1

Work Capacity Available in a Stream

Aim: To calculate the amount of available energy in a stream

This is a pencil-and-paper investigation. In it you will learn how scientists approach certain kinds of problems that are very difficult to solve through observation and experimentation. We will use an imaginary stream that has a gradient of 30 feet per mile and a uniform velocity of 5 miles per hour throughout the test mile. This stream is delivering 200 cubic feet of water per second. Let us examine some of the things we know about the stream.

1. Since the velocity is uniform throughout the test mile, what happens to the energy made available as the water is lowered 30 feet per mile?

   It is used to overcome friction.

2. The force of moving water can do work. The formula used to calculate force is $f = m\,v^2$. Since we are using the English system with this investigation, in what units will m (mass) and v (velocity) be measured?

   m will be measured in pounds and v in feet per second.

3. Since we need to know the velocity of the water in feet per second, how do we change it from miles per hour?

   5 × 5,280 divided by 60 × 60 equals 7.333

   ________ ft/sec

4. Water weighs 62½ pounds per cubic foot. What weight of water passes a point in one second?

   200 ft^3/sec x 62½ lb/ft^3 = 12,500

   ________ lb/sec

5. What is the force exerted by the moving water?

   12,500 lb/sec × 7.333 ft/sec = 672,162.5

   ________ ft-lb/sec^2

This is an investigation appropriate only to classes that have a good mathematical background and preferably have studied physical science in the 8th grade. If your school is in a suburban or rural area where there is a small stream available for study, you can make this a realistic investigation by using that stream. The following simple techniques will supply approximate data for your local stream.

Gradient: A light pole at least 6 feet long is painted alternately red and white in 6-inch bands. You will need a carpenter's level, 6 or 12 inches long, and a 100-foot tape measure, which you can probably borrow from the athletic department.

1. Measure a distance of 100 feet along the bank of the stream, following the curves. Mark the ends with small stakes.
2. Stand the marked pole beside the student who will be the levelman and make a mark on the pole at his eye level.
3. Have the levelman stand at the edge of the stream at the uppermost stake. Have the rodman stand at relatively the same height above water level at the lower stake and hold the pole in a vertical position.
4. Have a student hold the level in front of the levelman's eye and say "Now" when the bubble is centered in the arc. At that time the levelman, sighting along the upper surface of the level, notes where his line of sight intercepts the pole.
5. The difference between that point and the height of the levelman's eye is the stream's gradient in feet and fractions per 100 feet.

Velocity: Stretch pieces of string across the two widest points of the stream within the 100-foot test section, preferably at the 0- and 100-foot stakes.

1. Measure the distance along the stream course between the strings.
2. Post a student with three to five chips of wood at 0, or upper, string and another, with a stopwatch, at the downstream string.
3. The student with the chips drops one as far out from the bank as possible and the instant it touches the water calls "Now."

4. The downstream student starts the stopwatch on the signal "Now" and stops it when the chip passes under the lower string.
5. Repeat the timing three to five times. Use the *average* time recorded and the distance between strings to establish the velocity of the stream in feet per second.

Delivery:

1. Measure the width of the stream at the midpoint of the timing course.
2. Make five measurements of the depth of the stream at uniformly spaced intervals across the midpoint width.
3. Add these depths and divide by *seven* (the depth at both banks is 0).
4. The product of the mean depth and the width of the stream is a measure of its cross section in square feet.
5. Multiplying the cross section in square feet by the velocity in ft/sec will tell you its delivery in cubic feet.

6. Does this force change as the water flows through the test mile? Why?

No. It cannot change because neither the amount of water nor the velocity changes and one of them must change to alter the force.

7. What is the effect of gravity on water flowing down a slope where there is no friction?

Gravity accelerates the water according to the equation

$$a = g\frac{d}{s}.$$

8. Does gravity effectively change the velocity of the stream we are considering?

No; the stream flows at a uniform rate.

9. What is the effect of friction on water flowing down a slope?

It uses energy and slows the stream.

10. Did friction make any change in the initial velocity of the stream being studied?

No; the velocity was the same throughout the stream.

11. What happened to the increase in force caused by the gravitational acceleration in our stream?

Since acceleration did not increase the velocity of the stream, it must have supplied the energy needed to overcome friction.

12. What is the rate of acceleration for our stream? (See Section 17-1 in your textbook for an explanation of how to calculate acceleration.)

0.03 ft/sec^2

NOTE:

If your students omit the powers of foot and second in the answers to **A-5** and **A-13**, ignore it. Technically they should be included, but a foot or a second raised to any power is still just a foot or a second. The expression in these cases does not mean "a square foot" or "a square second."

13. Since there is no change in velocity in our stream, the accelerations (positive for gravity and negative for friction) exactly balance each other. What is the amount of force provided by the acceleration of our stream? See **A-2** for a clue.)

$f = 12{,}500 \text{ lb} \times (0.03 \text{ ft/sec}^2)^2 = 703.125$

$\text{ft}^2\text{-lb/sec}^4$

14. How much work is the stream doing to overcome friction at a particular point each second?

703.125 ft-lb

15. From **5** and **14** you can estimate the total power of the stream flowing by a point. What is it?

672,162.5 + 703.125 = 672,865.625 ft-lb

16. What part of the stream's total power is used to overcome friction?

(703.125/672,865.625) = about 0.0010, or 0.10 %

Isostasy

Aim: To demonstrate isostasy

MATERIALS
Pan, 9″ x 12″ x 2″
1-qt plastic bag
Elastic band
Pieces of wood, 8″ x 5″ x 1″ (2)
Sand, gravel, or small stones
Water
Pan partly filled with gelled gelatin
Piece of plastic wrap
Small bucket of dry sand
3″ x 5″ card

Use unflavored gelatin, which can be found in all food stores. To make the gel sufficiently firm, use one half to two thirds of the recommended amount of water. If possible, use straight-sided rectangular aluminum cake pans about 8″ x 12″. Substitutes can be formed of heavy kitchen aluminum foil, but they are not very satisfactory. Fill the pans about ½″ to ¾″ deep with the gelatin suspension and let them cool for one day before use. A 1-pound coffee can of sand is enough for each pan of gelatin. Dry, clean sand can be procured from any cement-mixing plant, if none is available otherwise. The piece of plastic film should be large enough to overlap the edges of the pan about 2″. Any of the plastic wraps available in food stores will do. One roll will supply enough material for a large class.

Step A Fill the plastic bag half full of water and seal it by twisting the top and winding an elastic band around it. Place the bag in the pan, with the sealed portion at one end. Put the two blocks of wood alongside one another on top of the bag.

1. Do the two blocks of wood float evenly on the bag? If not, note the difference in elevation of the upper surfaces.

If the blocks of wood are of equal mass per cm², they will float approximately evenly upon the plastic bag. Usually, because the bag does not fit the pan perfectly, there will be a slight difference of about 1–3 mm in the levels of the upper surfaces of the blocks.

2. Load both blocks of wood with sand, gravel, or small stones so that the top surfaces of the blocks are even.

NO. 2—

Usually it is necessary to put a little more sand on one block than on the other to bring them into alignment.

3. Remove the material from the top of one block and place it on the other. What happens?

The unloaded block rises, and the loaded block sinks.

4. What action that occurs on the earth is demonstrated in A-3?

One area is eroded and the debris is transported to and deposited on another. Thus, isostasy is demonstrated.

Step B Remove the blocks of wood and brush them off. Replace the blocks of wood and note their relative vertical positions.

5. Load one of the blocks with several ice cubes. What happens to the other block?

The block without a load rises.

The time involved depends upon the size of the ice cubes and the temperature of the room. A reaction usually will be noted in 10 minutes.

NOTE:

Let your pupils experiment with this setup to devise other demonstrations of isostasy. Blocks of wood can be used to represent blocks of the earth's crust for demonstrating block mountain building.

6. Set your investigation aside for a while, until the ice melts.

7. After the ice has melted, observe the relative positions of the blocks of wood. What has happened?

When the ice has melted completely, the two blocks will approach their original positions. The amount of meltwater absorbed will affect the masses of the blocks and prevent complete return to the original positions.

8. What geologic action have you imitated in **B-5** through **B-7**?

This step has demonstrated what occurs as a glacier forms and melts. It is an example of isostatic balance in the crust.

Step C Make a second demonstration of this principle in the following way. Cover the gelled gelatin in the pan with the plastic wrap so that there is a border of the thin plastic overlapping all edges of the pan. Pour sand into the pan until it is uniformly ½″ to ¾″ deep. Smooth the surface of the sand with a 3″ x 5″ card.

9. Gently pour sand into one end of the pan to form a "hill" about two inches high. What happens?

The loaded area sinks, and the rest of the surface rises a little.

10. When you built the "hill," what caused the gelatin layer underneath to sink?

Pressure from the mass of the sand

11. What raised the sand at the end of the pan opposite the "hill"?

Gelatin flowed out from under the area of increased pressure into areas of less pressure.

12. What caused the action you saw?

Isostasy

13. Build another "hill" at the end of the pan opposite the first hill. What happened when you built the hill?

The region under the second hill sank and the region between the hills bulged upward.

14. Use the 3″ x 5″ card to make the sand surface level again. See if you can again establish a "stable" situation.

15. What condition brings around a stable situation?

The surface again becomes level when the sand is spread uniformly over it. The situation is now stable because the sand exerts a uniform pressure on the gelatin.

Convection Currents

Aim: To study convection currents

MATERIALS
1-liter beaker
Bunsen burner, tripod, asbestos gauze mat
Water
Ink
Pipette

Step A Place the beaker on the asbestos gauze on the tripod. Fill the beaker ⅔ to ¾ full of water. With the pipette, carefully introduce about 10 ml of ink into the bottom of the beaker of water.

1. Why does the ink form a layer at the bottom of the beaker?

Because the ink is slightly denser than the water

Step B Light the Bunsen burner and place it underneath the beaker.

2. What happens as soon as you place the Bunsen burner under the beaker?

The ink layer begins to move.

3. What happens as the flame continues to burn under the beaker?

As heating continues, streams of colored water rise from the ink layer toward the surface.

4. How do you explain your observation in **B-3**?

The heated inky water has expanded, and its density has been lowered to slightly below that of the cool water above it.

5. What happens in the beaker after heating it a few minutes longer?

As all the bottom water becomes heated, there is a general mixing of inky and clear water. Downward drifting filaments of inky water may be observed toward the outer portion of the water in the beaker.

6. What have you produced in the beaker of water?

Convection currents

How Does Salt Affect Water?

Aim: To discover what salt does to water

MATERIALS	
400-ml beaker	Wire
Copper strips, 1″ x 6″ (2)	Table salt (NaCl), 10 g
Zinc strip, 1″ x 6″	Distilled water, 500 ml
Voltmeter	Balance and weights
Battery, 1.5 volt	100-ml graduated cylinder

The beakers may be replaced by ordinary glass tumblers or jelly glasses. Many physics laboratories have heavy tumblers with a terminal head with clamps for performing experiments similar to Steps C and E. Use these if you can obtain them. These sizes of the copper and zinc strips are ideal. However, smaller pieces will be satisfactory. The preferred voltmeter is one that reads to 5 volts and is so designed that the needle swings in both directions from zero. If your meters swing in only one direction, you must be sure to attach the battery and zinc to the proper terminal.

Step A In this step you will measure a few of the properties of water. Since you want pure water, you will have to use water that has been distilled to rid it of any impurities.

1. Weigh the 400-ml beaker as accurately as you can, at least to the nearest 0.1 g. What is the weight of the beaker?

(The weights will vary.) ______ g

2. With the graduated cylinder, measure 100 ml of distilled water and pour it into the weighed beaker. Be careful not to spill any water. Then weigh the beaker with the water as accurately as you can. What is the combined weight of the beaker and the water?

Be sure the students use the bottom of the meniscus as the measuring line on the water surface and that they read it with the 100-ml line held at eye level.

______ g

The weight should be close to the weight in **A-1**, plus 100 g.

3. Compare the weight of the empty beaker with that of the beaker filled with water. Is the difference in weight what you expected it to be? Explain your reasoning.

The combined weight will not be precisely 100 g greater than that of the empty beaker. Usually it will be a few tenths of a gram less than expected, since water clings to the inside of the graduate and because the graduate is not calibrated finely enough to measure precisely 100 ml.

4. Weight out approximately 3.5 grams of table salt. What is the exact weight of the salt, to the nearest fraction of a gram?

____________g

The salt should be weighed to an accuracy of at least 0.1 gram.

5. Add this salt to the water in the beaker and gently swirl it until it is completely dissolved. What is the weight of the beaker with its salty water?

____________g

6. Is the weight you measured in **A-5** exactly the sum of the weights in **A-2** and **A-4**? Why?

Any reasonable answer is acceptable.

This weight should be close to the sum of **A-3** and **A-5**.

7. Pour the salty water into the graduated cylinder. What is the volume of the salty water? (Save this solution for Step D.)

____________ml

There will be less than 100 ml. Water will adhere to the beaker.

8. Explain the difference, if any, between the measurement in **A-7** and the 100 ml of distilled water you used in **A-2**.

Any reasonable answer is acceptable.

The best estimate of the density to thousandths place will be 1.0??, with the two missing numbers (??) the weight of the added salt in grams and tenths. Example: If 3.4g were used, then density would be 1.034 g/cm³.

9. What is your estimate of the density of your salt water?

____________g/cm^3

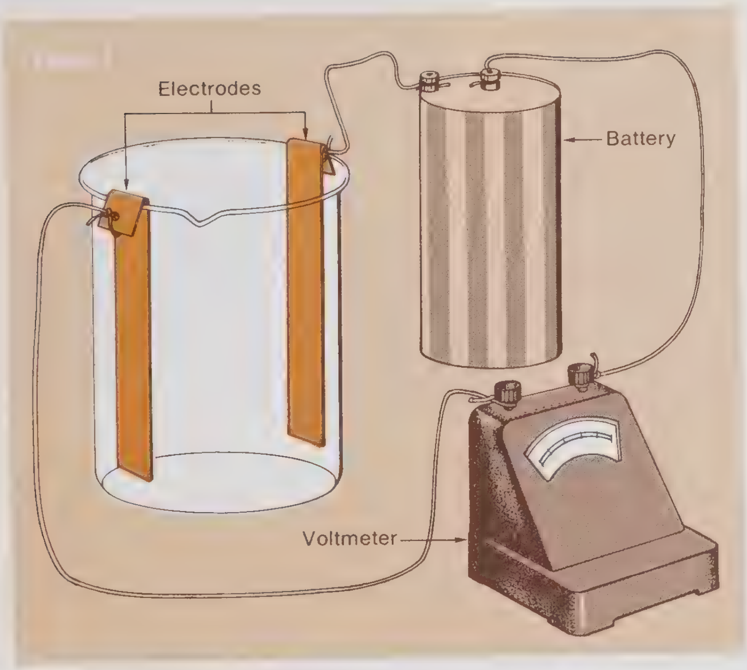
NO. 10—

Actually, the salt increased the density of the solution. The density of the water itself did not change.

10. What effect did the addition of salt have upon the density of the water?

The salt increased the density of the water.

Step B Carefully rinse the 400-ml beaker with two changes of tap water and then with some distilled water. Dry the inside of the beaker with a paper towel. Arrange the two copper electrodes as shown in Figure 1. Be absolutely sure that the electrodes do not touch one another.



11. Read and record the position of the needle on your voltmeter.

_____________volts

Laboratory voltmeters often do not register 0 when at rest unless care is taken to adjust the needle to the zero point.

12. Add about 100 ml of distilled water to the beaker. What is the voltmeter reading?

_____________volts

There should be no movement of the needle.

13. Does the distilled water conduct an electric current?

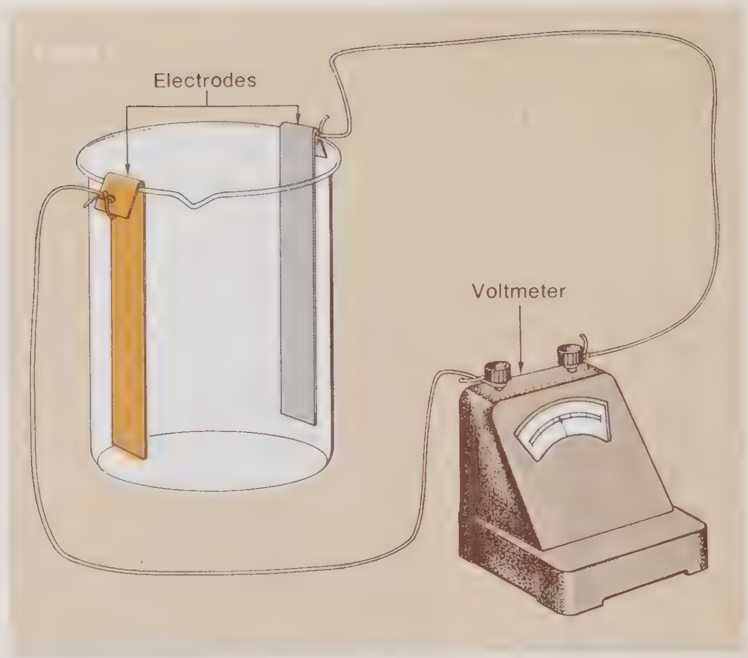
No

Step C Replace one of the copper electrodes with a zinc one. Remove the battery from the circuit and connect the voltmeter directly to the electrodes as shown in Figure 2.

14. Lower the electrodes into the distilled water in the beaker. What is the voltmeter reading?

_____________volts

There will be no change in the needle position if the electrodes used are clean. A small amount of salt from one of the electrodes may cause the needle to flick a little.



15. Did the distilled water produce an electric current in the presence of two different metal electrodes?

No

Step D Use the same circuit that you used in Step B.

The needle will move to between 1.0 and 1.5 volts.

16. After placing the electrodes in the beaker, add the salt water you saved in the graduated cylinder. What does the voltmeter read?

__________volts

17. How do pure water and salt water differ in their behavior in Steps B and D?

Salt water conducts electric current; pure water does not.

Step E Use the same circuit you used in Step C.

The needle will move to somewhere between 0.9 and 1.4 volts.

18. After replacing the electrodes in the salt water, what is the voltmeter reading?

__________volts

19. How do pure water and salt water differ in their behavior in Steps C and E?

When two different metals are immersed in salt water, a current flows through the circuit. This does not happen with pure water.

20. From what you learned in this investigation, how would you explain why salty seawater corrodes metals more rapidly than does fresh water?

The ions in salt water attack the metal and cause it to dissolve. This does not happen in fresh water as rapidly as in salt water because there are many fewer salts in fresh water.

Measuring the Force of Gravity

Aim: To measure the force of gravity

MATERIALS
Pendulum bob
Ring stand
Stopwatch
String
Yardstick

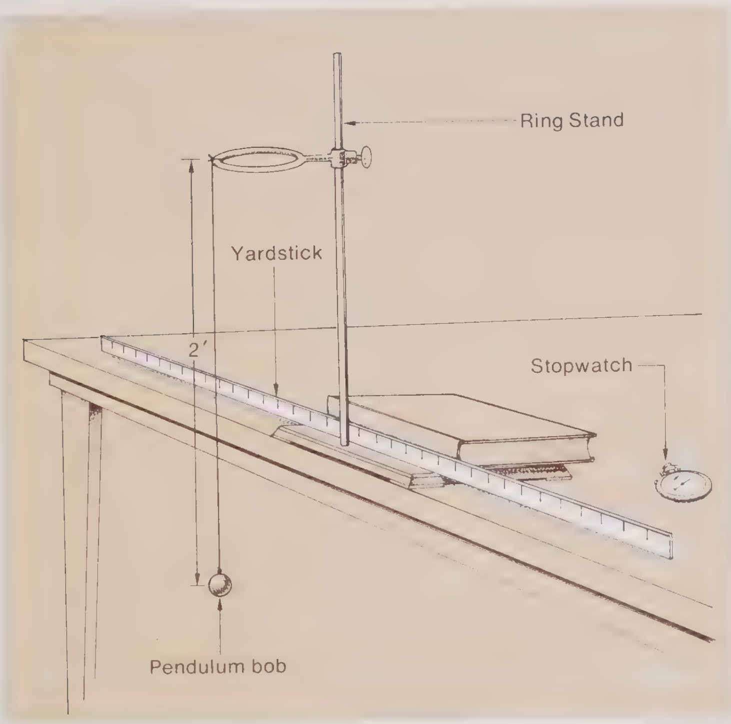
Pendulum bobs can be borrowed from the physics lab, or you can use plumb bobs, heavy nuts, or lead sinkers as substitutes. Students should work in pairs or groups of three. Each group will need one of each item in the materials list.

Step A You will work in groups for this investigation. Set up the apparatus as shown in Figure 1, tying the string to the edge of the ring so that the pendulum is 2 feet in length and can swing freely. Set your textbook on the back of the ring stand to stabilize it. Hold the pendulum bob high and let it drop.

Depending on the number of students in a group, allocate the tasks of timing, swinging the pendulum, and recording the data. If possible, include in each group one student who is mathematically proficient. It is extremely important that the timing be done exactly.

1. Does it accelerate as it drops? Yes

2. What force causes it to accelerate? Gravity



The data given here as a sample was collected at an elevation of 300′. The theoretical force of gravity at sea level is 32 ft/sec^2; therefore, answers will vary according to your altitude and latitude. In addition, answers will vary according to the amount of friction in the system, the accuracy of making the pendulum a specific length, and the accuracy of timing and calculation. Answers between 29 and 33 are acceptable.

Step B Now you will measure the force of gravity in your location.

The pendulum swings in a complete cycle when it goes from position 1 to position 2 and back to position 1 again, as labeled in Figure 2. Hold the pendulum bob at an angle of approximately 15° from the ring stand, as shown in Figure 2. The timer should practice starting the watch at the exact moment when his lab partner drops the pendulum bob.

3. Time 5 cycles of the pendulum. How many seconds does this take?

______8______sec

4. To calculate the force of gravity, use the following formula: $T = 2\pi \frac{l}{g}$, where T = time for one cycle, l = length of pendulum, and g = gravity. Make the appropriate substitutions in the formula and solve for g. Remember to keep the time in seconds and the distance in feet. Make your calculations to two decimal places. (Hint: Square the terms on both sides of the equation to eliminate the square root.)

$$T = 2\pi\sqrt{\frac{l}{g}}$$

In this instance: $T = \frac{8 \text{ sec}}{5 \text{ cycles}} = 1.6 \text{ sec}; l = 2 \text{ ft}$

Squaring both sides of the equation and substituting gives:

$$2.56 \text{ sec}^2 = (2)^2\,(3.14)^2\left(\frac{2 \text{ ft}}{g}\right)$$

Transposing and combining terms gives:

$$g = \frac{(2)^2\,(3.14)^2\,(2 \text{ ft})}{2.56 \text{ sec}^2}$$

Solving for g: $g = \frac{(4)\,(9.87)\,(2 \text{ ft})}{2.56 \text{ sec}^2}$;

$$g = \frac{80.96 \text{ ft}}{2.56 \text{ sec}^2};$$

$g =$ ____31.62____ft/sec^2

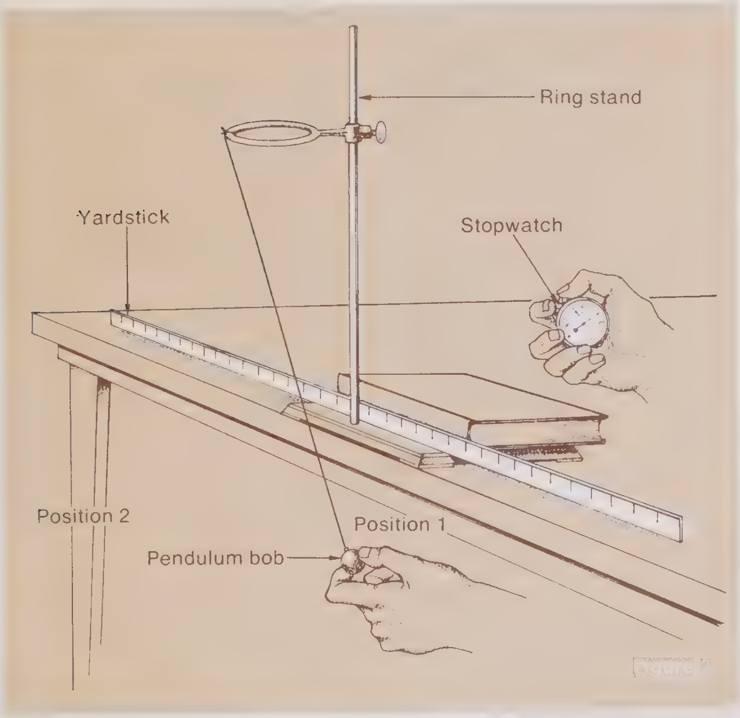
Step C Repeat this investigation, using different pendulum lengths and timing various numbers of cycles.

5. Does the force of gravity vary with different pendulum lengths?

No

6. Does it vary when you time different numbers of cycles?

No



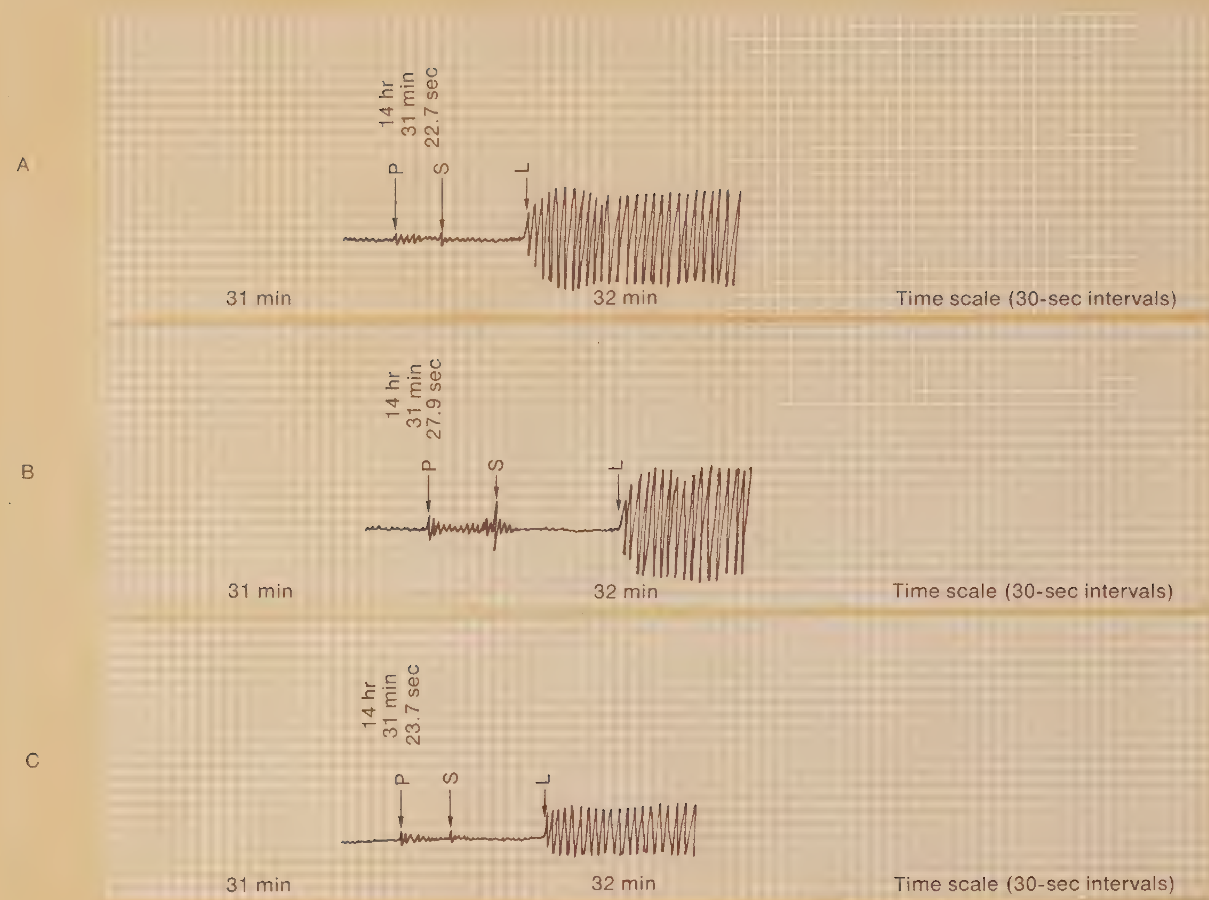

A
14 hr
31 min
22.7 sec
P
S
L
31 min
32 min
Time scale (30-sec intervals)
B
14 hr
31 min
27.9 sec
P
S
L
31 min
32 min
Time scale (30-sec intervals)
C
14 hr
31 min
23.7 sec
P
S
L
31 min
32 min
Time scale (30-sec intervals)

Figure 1

This is a pencil-and-paper investigation that requires precision for a satisfactory solution. If millimeter scales are not available, English scales divided to 1/16″ will suffice. In both cases the students should be instructed to estimate measurements to the nearest 0.1 of the graduations.

Locating an Epicenter

Aim: To locate the epicenter of an earthquake

MATERIALS
Millimeter scale Pencil compass

Step A Figure 1 represents the seismographic record of an earthquake as recorded at three separate stations. You will find the first indications of P-, S-, and L-waves recorded.

1. Using the millimeter scale, determine the difference in the time of arrival of the P- and S-waves at each of the three stations, and record this information in the table below.

Station	Time Intervals
A	7.1 sec
B	10.7 sec
C	8.0 sec

The time intervals are found by solving proportions for the time interval:

$$\frac{\text{P to S distance}}{\text{30 sec distance}} = \frac{\text{P to S time}}{30}$$

If errors are greater than 0.5 sec, have the student repeat the measurement.

Step B When the time interval between the arrival of the P-wave and the S-wave is known, the distance to the epicenter can be estimated. For a nearby earthquake, the distance estimate is made by multiplying the time interval by 8.9 km/sec.

2. Estimate the distance between each station and the epicenter, and fill in this information in the table that follows.

Station	Distance
A	65 km
B	95 km
C	71 km

NO. 2—

If errors are greater than 5 km, have the student repeat Steps A and B.

If you have a class of mathematically able students, or if you have one such student in the class, we suggest that these students use an alternate method for computing the distance to the epicenter. This method is based upon the facts that P- and S- waves originate at the same instant and travel to the station at different speeds. In each case, the simple time-rate-distance relationship applies. However, all that is known about time is the lag in travel time of the S-wave. This lag is the difference between the times of arrival of P- and S-waves and is symbolized by delta, Δ. The symbol t is used for the travel time of the P-wave. This is the unknown that is sought. The numbers are the rates of travel of the two kinds of waves.

Therefore:

$$5.8\,t = 3.5\,(t \div \Delta)$$

The algebraic transformation of the equation is stated in the student material so that t is alone on one side of the equation.

Using an alternate method, it is possible to calculate the time when an earthquake occurred from the difference in arrival times of the P-wave and the S-wave. Once the time is known, the distance from the station to the epicenter can be calculated. The equation for estimating how long the earthquake wave traveled before it reached the station is this:

$$5.8\,t = 3.5\,(t \div \triangle) \qquad (1)$$

when 5.8 km/sec is the speed of the P-wave, 3.5 is the speed of the S-wave, and $\triangle$ is the difference in the time of the waves' arrival at the station. Equation (1) can be transformed by algebra into a more easily solved form by these steps:

$$5.8\,t = 3.5\,t \div 3.5\,\triangle \qquad (2)$$
$$5.8\,t - 3.5\,t = 3.5\,\triangle \qquad (3)$$
$$2.3\,t = 3.5\,\triangle \qquad (4)$$
$$t = 3.5\,\triangle/2.3 \qquad (5)$$

Solution for t will vary with the accuracy with which measurements are made in **A-1**. They should be within 0.5 sec of the results indicated.

3. Solve for t for each of the three stations, using the differences you found in **A-1**. Fill in the information in the table below.

Station	P-wave travel time to station
A	11.1 sec
B	16.3 sec
C	12.2 sec

The computed distances should be within 3 km of the results indicated.

4. Using the rate 5.8 km/sec and the times you found in **B-3**, estimate the distance to the epicenter of the earthquake from each station, and record it below.

Station	Distance to epicenter
A	64.3 km
B	94.5 km
C	70.9 km

STEP C—

The precision with which the compass is used affects the accuracy by which the epicenter is located. Use the scale at the bottom of the page on which the plotting is done. Notice that to the left of 0 km there is a short stem divided into kilometers and to the right of 0 km the bar is divided into 10-km units. When the compass point is up at the proper unit, extend the pencil to the proper ten's place. The pencils used must have the sharpest possible points.

Step C Once the distance to the epicenter is known, its location can be estimated graphically. In Figure 2 you will find each of the three observation stations marked with its proper letter. With a compass set for the proper distance between the epicenter and Station A, draw a circle with

Station A as the center. Do this for each of the three stations.

5. Why do the three arcs not intersect at one point?

A variety of errors account for the triangle of error that will result from drawing the three arcs: improper measurement of the P to S distance on the seismograms, improper setting of the compass, and careless drawing of the arcs. The depth of the focus is a natural cause for the triangle.

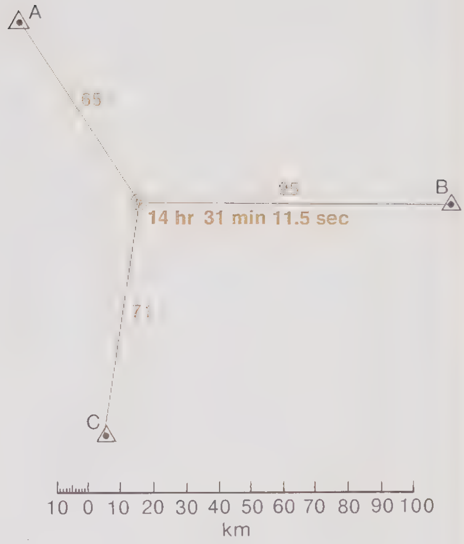


Figure 2

6. Place a dot in the middle of the "triangle of error." Call this the epicenter. Measure the distance from the epicenter to each station and record it below.

The distance from the center of the triangle of error to each station should approach the distances noted in **B-2** above.

Station	To epicenter
A	km
B	km
C	km

7. From the speed of P-wave (5.8 km/sec) and the distance you measured and recorded in **C-6**, calculate how long it took the wave to travel from the epicenter to each of the three stations, and record it below.

The travel time is best estimated from the measurements made in **C-6**. The results of this calculation should be within 0.5 sec of the times indicated.

To station	Travel time
A	11.2 sec
B	10.4 sec
C	12.2 sec

The time of arrival of the first P-wave at a station minus the travel time computed for that station yields the estimate of the time the earthquake occurred. For all stations it should be within 0.5 sec of 14 hr 31 min 11.5 sec.

8. From the data on the seismograms and the travel times you calculated for **C-7**, estimate when the earthquake occurred in relation to each station, and record this information in the following table.

Station	Time of Earthquake		
A	hr	min	sec
B	hr	min	sec
C	hr	min	sec

9. Take the average of the three times in **C-8**. This is the best estimate of when the earthquake occurred. When did it occur?

14 hr 31 min 11.5 sec

Refraction of Light Rays

Aim: To study refraction

MATERIALS	
Beaker of water	Piece of white paper
Pencil	Ruler
Piece of plate glass (1/4″ thick)	Common pins (3)

Glass tumblers or even paper cups can be substituted for the beakers.
The physics department of your school probably has squares of thick plate glass for use in this investigation. Squares that are cut carelessly are not satisfactory because the opposing edges usually are not parallel and are not planes. Any school supply house handling general science or physics materials stocks cut squares with polished sides.

Step A Refraction is a wave phenomenon. The same rules govern refraction of elastic waves in rocks that govern refraction of light waves. It is much easier to study light waves than elastic waves. What we learn from light waves, we can apply to elastic waves. Hold a pencil diagonally in a beaker of water. Look directly down upon it.

STEP A—

The pencil *must* be held at an angle of less than 90° to the surface of the water, and the observation *must* be made from above and slightly to the side of the plane of the pencil.

1. What apparent change do you observe in the shape of the pencil?

It appears to be sharply bent where it enters the water.

2. Through what medium did the light rays pass that let you see the part of the pencil out of the water?

The air

3. Through what did the light rays pass that allowed you to see the part of the pencil under water?

Through water and air

4. In reference to **A-3**, where did the apparent bending of the pencil take place?

Where the light rays had to pass from one medium to another

5. Are the media involved in seeing the pencil under water different in density? Which is denser?

Yes. The water is denser than the air.

6. Where did the apparent bending of the pencil take place with respect to densities?

The bending took place where the density changed.

The answer will vary depending upon the alignment of pins 1 and 2. The ray will be bent toward the perpendicular to the interface.

Step B Place the piece of plate glass flat on a piece of white paper. Place a common pin upright at the edge of the glass that is away from you. Place another pin upright about two inches from the first pin and beyond it so a line through the pins strikes the edge of the glass at other than a right angle. Look through the glass edgewise. Move your head to align the images of the two pins. Place a third pin upright at the edge of the glass nearer you so it is in line with the *image* of the first two pins aligned by sighting. Carefully remove the piece of glass. Draw straight lines from the first pin to the second and from the third pin to the first.

7. Do the two lines you drew form a straight line?

No

8. If you continue the first line you drew, between pin 1 and pin 2, does it pass to the left, or right, of pin 3?

9. What caused the path of the light ray from pin 1 to pin 2 to bend to pin 3?

The light ray was bent by the change in material, or density, as it passed from air into glass.

Step C Repeat Step B several times. Each time, have the line between pin 1 and pin 2 at a different angle to the edge of the glass. Include one experiment with that line perpendicular to the edge and at least one experiment on each side of the perpendicular. Study your results.

10. Was the light ray bent when the line from pin 1 to pin 2 was perpendicular to the edge of the glass?

No

11. Was the light ray bent when the line from pin 1 to pin 2 was not perpendicular to the edge of the glass?

Yes

12. When the light ray was bent, did it bend toward or away from the line perpendicular to the edge of the glass?

It bent toward the perpendicular to the interface, the edge of the glass.

13. When the light ray traveled from pin 2 to pin 3, did it pass from more dense to less dense, or from less dense to more dense, material?

From less dense to more dense material.

14. What would happen to a light ray passing from glass into air?

If it passed the interface at other than a right angle, it would be bent away from the perpendicular.

Step D Examine Figure 1. It represents a beam of waves moving at an angle through an interface, a discontinuity that occurs between a less dense and a more dense medium. The dashed line is perpendicular to the interface. The line with arrow points on it is the path of a ray. The parallel lines are wave fronts advancing at a uniform rate per second. Notice that the path of the ray always is perpendicular to the wave front.

15. Which medium, A or B, is the denser? Why?

B is the denser medium because the ray is bent toward the perpendicular as it passes the interface between A and B.

16. Study the spacing between the wave fronts. Remember that the spaces represent uniform intervals of time. In which medium is the wave front moving forward most rapidly? Why?

It is moving most rapidly in A because in a given interval of time the wave front travels farther in A than in B.

17. Study your answers to **D-15** and **D-16**. What is the effect of density upon the speed at which a wave front moves through a medium?

The denser the medium, the slower the advance of the wave front.

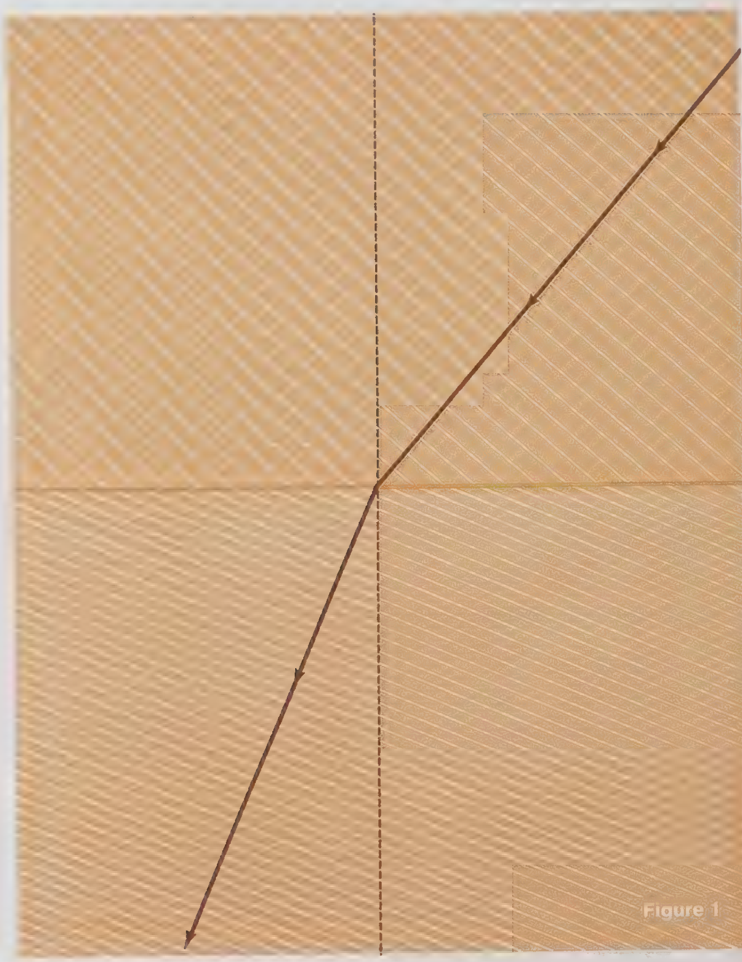


Figure 1

Impact Craters

Dissecting trays, baking pans, or aluminum foil pans can be used instead of a sand box. The sand should be sifted and should be perfectly dry. The ball bearings should be about 0.4″ to 0.5″ in diameter. Damaged ones can usually be obtained from a garage and should be washed free of grease with gasoline. If you cannot find steel ball bearings, glass marbles can be used. However, because of their lower density, they do not make as satisfactory a crater as do ball bearings.

Aim: To study the shapes of impact craters

MATERIALS
Sand box, 12″ x 12″ x 3″ Dry, clean sand (enough to fill the box) Large steel ball bearings (3 or 4)

Step A Fill the sand box to within an inch of the top with clean, dry sand. Smooth the surface with your hand, a ruler, or a piece of cardboard. Place the box on the floor and, standing on a chair or stool, drop a ball bearing into the box. Observe what happened at the point of impact.

1. What is the shape of the crater?

Circular

2. What has happened to the surface of the sand immediately surrounding the crater?

(The ejecta rim is not easily seen. However, keen-eyed students will see it as a slightly raised ridge around the crater.)

3. Draw a cross section of the crater and its immediate surroundings.

4. Repeat the investigation, having a partner drop the ball bearing as you observe closely what happens. What did you observe?

As the ball bearing struck the sand, sand spurted up

and fell back forming the rim.

Step B Alternate with your partner in throwing the ball bearing at the sand and observing the impact. Start by throwing at an angle that is close to the perpendicular and with each throw increase the angle from the perpendicular.

5. What change in the shape of the crater did you observe when the angle of throw was less than 45° from the perpendicular?

The crater appeared to be circular for all throws.

6. How did the shape of the rim change as the angle of incidence increased from 0° (perpendicular) to 45°?

As a 45° angle of incidence was approached, the rim facing the direction of the throw may have been a little higher than the rim on the opposite side of the crater.

7. When the angle of the throw was greater than 45° from the perpendicular, how did the shape of the crater change?

The crater did not change appreciably from circular until the angle approached 60°. Then the crater was slightly elliptic. When the direction of throw was almost parallel with the surface of the sand, the ball bearing made an elliptic scar and bounced off the sand or rolled on the surface.

8. As the crater shape became noticeably elliptic, what happened to the cross section of the rim?

The more elliptic the crater became, the more the side of the rim in the direction of the throw differed from the opposite side.

Step C Meteor craters are impact craters formed in much the same way you made craters in the sand.

9. Almost all known meteor craters are circular, or very nearly circular, in shape. Does this mean that the meteor came straight down to earth in a line perpendicular to the surface? Why?

It does not. Circular or almost circular impact craters are formed through a wide range of angles of incidence.

10. All known meteor craters have a noticeable rim that rises above the surrounding countryside. How is that rim formed, and what was the source of the material that composes the rim?

Much of the rim is formed from material blasted out of the crater by impact.

Magnetism

Aim: To reveal the magnetic field around magnets

MATERIALS
Bar magnet
Horseshoe magnet
Piece of paper
Container of fine quartz sand
Container of fine iron filings

You can probably obtain magnets and iron filings from the physics or general science department of your school. The filings and the sand should be in shaker cans. Ordinary table salt cellars make satisfactory shakers. Caution your students to keep the magnets covered with paper while they are doing these experiments. Since there is no easy way to remove loose iron filings that get onto the magnets, you may wish to wrap the magnets in thin plastic bags such as those used for sandwiches.

NOTE:

If the sand contains black specks of magnetite, they may become arranged in the magnetic field.

Step A Place the bar magnet flat on your desk. Cover it with a sheet of paper so that the magnet is more or less under the middle of the sheet. Lightly sprinkle fine quartz sand on the paper over and around the magnet.

1. What do you observe?

   The sand particles are randomly scattered.

2. Carefully lift the paper from the magnet and pour the sand back into its container.

Step B Arrange the magnet and paper as you did for Step A. Lightly sprinkle fine iron filings on the paper.

3. What do you observe?

   The iron filings arrange themselves in a pattern of concentric or parallel lines.

4. Where is the pattern most strongly developed?

   At the ends of the magnet.

5. What does this indicate about the strength of the magnet?

The magnetic force is strongest at the ends of the magnet.

6. Draw a diagram of the arrangement of the iron filings.

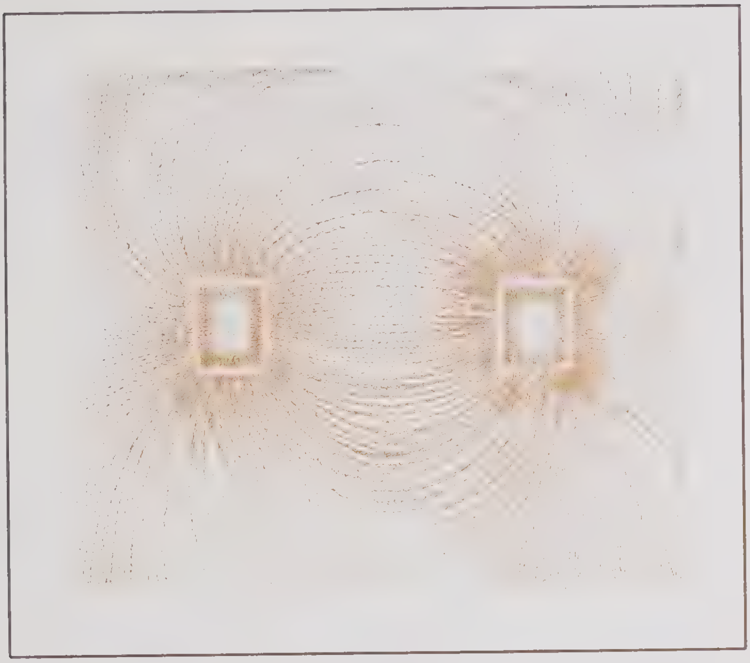
7. Carefully lift the paper from the magnet and return the filings to their container.

Step C Repeat Step B, using the horseshoe magnet.

8. Where is the pattern of iron filings most strongly developed?

Between the opposed ends

9. Make a diagram of the pattern formed.



10. How does the pattern in Step C differ from that in Step B?

In Step C the strong pattern is *between* the poles; in Step B it is *around* both poles.

11. In which step does the pattern more closely resemble what you know of the earth's magnetic field?

The pattern seen in C-8 bears more resemblance to the situation on earth than does that in B-3. However, neither duplicates the pattern characteristic of the spherical surface of the earth.

12. Carefully lift the paper and return the filings to the proper container.

Effect of Heat on Magnetism

Aim: To determine the effect of intense heat on magnetism

MATERIALS
Nail, 10d iron
A solenoid, or 10 feet of silk- or lacquer-insulated 14-gauge copper wire
Laboratory forceps
Iron filings, or a few very small iron tacks
Small magnetic compass
Bunsen burner
"D" battery

Be sure to test the iron nails you use to see if any have acquired magnetism. Discard those that have. Either common or finishing nails are satisfactory, and they may be 8d, 10d, or 12d size. If you cannot borrow solenoids from the physics department, use the wire-wrapping technique to produce the same effect. Caution your students to keep the circuit closed no more than a few seconds. A flow of current for only a fraction of a second will magnetize the nail. It is best not to use a storage battery as a source for the direct current, since it is safe only in the hands of an adult who knows about batteries. All that is needed with any battery is a single make-and-break connection. The small magnetic compasses used in general science are adequate. The smallest-possible iron tacks are better than iron filings because they are easier to account for and clean up.
If straight forceps are not available, use crucible tongs. You must use a Bunsen flame or its equivalent to produce the necessary intensity of heat. Alcohol lamps, etc., are not satisfactory.

Step A

1. Test the iron nail for magnetism, using the materials given to you. How can you tell the nail is not magnetized?

It does not attract iron.

2. Place the nail in the solenoid and close the circuit through it for a few seconds, or wrap the insulated copper wire around the nail as neatly as you can. Attach one end of the wire to one terminal of the "D" battery and leave the other end free. Place the wrapped nail on a level surface. Hold the free end of the wire against the unused terminal of the battery for a few seconds.

3. Remove the nail from the solenoid, or slip it out of the coil of wire. Repeat the tests you used in **A-1**. How do you explain the differences you observe?

The nail does attract iron and it causes the compass needle to follow; therefore, the nail is magnetized.

Step B Light the Bunsen burner and adjust it to get a clear blue flame. Hold the nail in the forceps and heat the nail to redness in the upper blue cone of the Bunsen flame.

4. Repeat the test you used in **A-1**. How do you explain the effects that you observe?

The nail does not attract iron; therefore, it is not magnetized.

5. Would you expect molten iron to be magnetic? Why?

No. Long before the iron is hot enough to melt, it loses its capacity to become magnetized.

6. Would you expect the outer core of the earth to be magnetic? Why?

No. The outer core of the earth is considered to be molten iron-nickel.

Lines of Magnetic Force Around an Electrified Wire

Aim: To demonstrate the lines of magnetic force around an electrified wire

MATERIALS
Dry cell
Bare copper wire, 12-gauge
Thin cardboard
Fine iron filings

Divide the students into teams of two, one student to hold the cardboard and tap it gently while the other closes the circuit. The circuit must not be closed for more than a few seconds. It is recommended that you use bare 12-gauge copper wire rather than insulated wire. The bare wire will get hot in the operator's hand, preventing him from keeping the circuit closed too long. Use 1.5-volt cells.

Step A Arrange your apparatus as shown in Figure 1. Lightly sprinkle some iron filings on the cardboard around the wire.

1. Are the iron filings in an orderly pattern or are they randomly distributed?

They are randomly distributed.

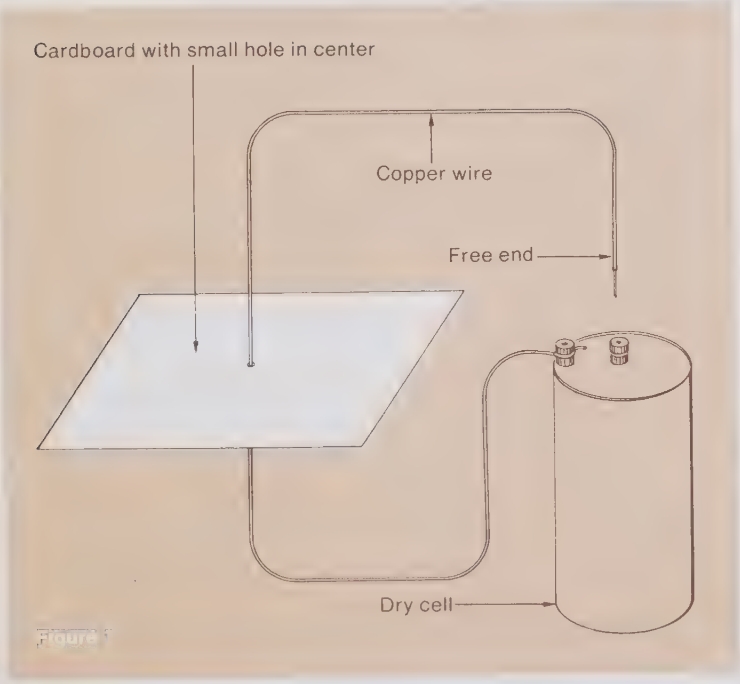


Figure 1

Step B Touch the free end of the wire to the middle terminal of the battery. Gently tap the cardboard. Remove the free end of the wire from the middle terminal.

2. What happened to the iron filings?

The iron filings nearest the wire arranged themselves in lines that are concentric to the wire.

3. What caused the action you noted in **B-2**?

A magnetic field was established around the wire as the current flowed through it.

Step C Gently tap the cardboard.

4. What happened?

With the current off, the tapping disturbed the concentric pattern.

5. How were the conditions in Step B different from those in Step C?

In Step B, a magnetic field was present and the tapping allowed the iron filings to align themselves with it. In Step C, there was no magnetic field and the tapping disturbed the pattern found in Step B.

6. What do you conclude from this investigation?

When a copper wire carries a direct current, a magnetic field exists around it.

Phases of the Moon

Aim: To investigate the phases of the moon

MATERIALS
Ping-Pong ball
Straight pin
Flashlight
Household cement

Styrofoam balls, 1½″ in diameter, are good substitutes for Ping-Pong balls. The styrofoam balls may be skewered on dissection needles.

Step A Put a little household cement on the head of the pin. Press the head of the pin against the Ping-Pong ball so that when the cement hardens, the pin will be a handle for the ball. Darken the room. Consider the light from the flashlight to be light from the sun and the Ping-Pong ball to be the moon. You are an observer and you represent the earth.

1. Stand about 6 feet from the flashlight, which is directed toward you and illuminated. Hold the Ping-Pong ball by its "handle" at arm's length so that you are at the right angle of a triangle made by you, the "sun," and the "moon." How much of the "moon" is illuminated? How much of the illuminated "moon" do you see?

Essentially half of the "moon" is illuminated, but only half of the illuminated surface is visible to the observer in this part of the investigation.

Unless the "moon" is held above head height throughout this turn, the "moon" will be eclipsed as it passes into the shadow of the observer.

2. Holding the "moon" at arm's length, slowly turn through 360°. What change takes place in the area of the surface of the "moon" that is illuminated?

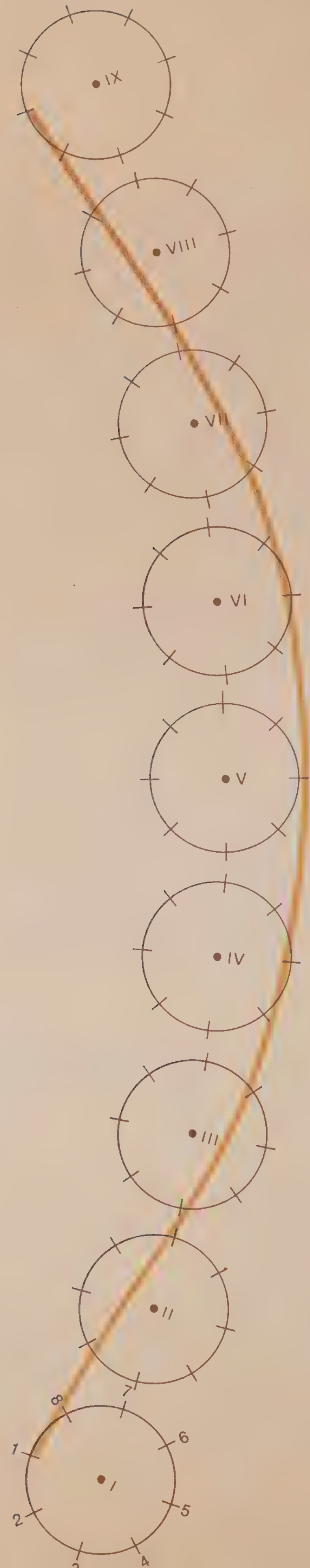
There is no change in the size of the illuminated area.

3. In **A-2**, what changes did you observe in the size of the portion of the illuminated surface of the "moon" that you saw, considering yourself as the earth?

If the turn is started from the position assumed in A-1, then the visible portion of the illuminated area increases until the entire illuminated area of the "moon" is visible when the observer is between the "moon" and the source of light. From that point in the turn until the "moon" is directly in between the source of light and the observer, the visible portion of the lighted area

decreases to zero. It then increases to half the illuminated area.

Step B Consider the sun, moon, and earth as shown in Figure 1. For each of the numbered positions of the moon, arrange your "moon," "sun," and yourself as earth. Observe carefully the illuminated surface that you, as earth, can see. Draw the illuminated area on the proper moon disk in the diagram. Shade the part of the disk that is NOT illuminated.


IX
VIII
VII
VI
V
IV
III
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1
2
3
4
5
6
7
8

The Path of the Moon in Space

Aim: To discover the path of the moon in space

Step A First let us consider the earth and the moon from the point of view of an observer on earth.

1. To an observer on earth, what is the apparent movement of the earth?

The earth has no apparent movement to an observer on earth. All the observable celestial bodies appear to move.

2. To an observer on earth, what is the apparent movement of the moon?

The moon appears to circle the earth very slowly from west to east.

Step B Now consider the earth-moon pair from the point of view of an observer on the sun.

3. To an observer on the sun, what would be the apparent motion of the earth?

The earth would appear to circle the sun.

4. To an observer on the sun, what would be the apparent motion of the moon?

The moon would appear to circle the earth.

This is a pencil-and-paper investigation that may be assigned as homework or done in class. If you wish to diagram the investigation on the chalkboard, draw as flat an arc as you can so long as it subtends a central angle of 30°. The 28-day period for a lunar orbit occurs along 27.7° of that arc. The lunar orbit need not be in scale; the figure is not. The earth travels along its orbit about 1.6×10^6 miles a day, and the lunar orbit has a radius of about 0.25×10^6 miles. Thus, to be in scale the lunar orbit would be inconveniently small for the plotting required of your students.
This is a good time to emphasize that the different apparent paths of the moon and the earth are relative to the point of observation. This is part of the idea embodied in Einstein's theory of relativity.

Step C Figure 1 shows a small part of the path of the earth in its orbit around the sun. The earth travels along the path from position I through position IX in 28 days. During that time the moon has made an apparent orbit around the earth. The point adjacent to each Roman numeral represents the earth, and the circle around it represents the orbit of the moon observed from the earth. There are eight uniformly spaced points on the circle that represents the moon's orbit. On the orbit that surrounds earth position I, these points are numbered 1 through 8. The moon moves from point 1 when the earth is at position I, to point 2 when the earth is at position II, and so forth. When the earth reaches position IX, the moon will have made a full apparent orbit around the earth. You will now plot the actual course of the moon as if it were observed from a point in space from which you could look perpendicularly at the plane of the earth's orbit around the sun.

5. On each of the lunar orbit circles, mark the position of the moon for that particular earth position on its orbit.

6. Connect the series of points that you have marked with either straight lines or a smooth curve, whichever is easiest for you.

7. Examine what you have drawn. How would you describe the path followed by the moon?

The moon does not appear to circle the earth when observed from deep space. Instead the moon appears to weave back and forth, sometimes on the sun-side and other times on the opposite side of the earth, sometimes ahead of and sometimes behind the earth.

8. The sun is traveling in an orbit through the Milky Way in much the same way that the earth is traveling in an orbit around the sun. What do you suppose the path of the earth appears to be in space?

The path of the earth from space does not appear to circle the sun but describes the same sort of sinuous path that the moon describes about the earth.

Teacher's Demonstration:

EFFECT OF O_2 ON PYRITES

To demonstrate the effect of oxygen on pyrites (a sulphide mineral) you need to demonstrate the following: (1) oxygen in dry air has little or no effect over a short time, (2) water with no air in it has a minimum effect over a short time, and (3) the combination of oxygen and water vapor does have an effect in a short time.

1. Powder a small amount of pyrites.

2. Place a pinch of the powdered pyrites on a piece of dry filter paper or a small piece of paper towel. Place this on a watch glass. Fill the lid of a mayonnaise jar with anhydrous calcium chloride, and put the watch glass and its contents on top. Place a ring of nondrying modeling clay around the base of the jar lid and invert a tumbler or jelly glass over the assembly. Press the rim of the glass into the clay to make a tight seal.

3. Place a pinch of the powdered pyrites in a test tube. Fill the test tube with *freshly boiled* distilled water. Stopper the tube with a rubber stopper. Dry the stopper and pour melted paraffin over it to seal it.

4. Place a pinch of powdered pyrites on a piece of moist filter paper or paper towel on a watch glass. Cover it with a jelly glass or tumbler. Add a drop or two of water each morning to keep the paper moist.

5. Set the experiments aside where they can be observed daily. In the first setup (No. 2 above) you have exposed the pyrites to dry air. The calcium chloride will reduce the water vapor in the trapped air to a negligible amount. In the second setup (No. 3 above) boiling the distilled water will remove the dissolved air and leave the pyrites exposed only to water. In the third (No. 4 above) you have exposed the pyrites to both water and oxygen.

After a few day—in some areas, a week—the pyrites in water will show a slight "weathering" from the action of the water. The powder may have a slightly rusty tinge. The pyrites exposed to water and air will have a great deal of rust, and the paper will be stained. The pyrites exposed to dry air will be unaffected. If you test the moist paper in the third setup with litmus, it will give an acid reaction, since sulphuric acid was formed. The water in the test tube for the second setup may or may not give an acid reaction.

Teacher's Demonstration:

LOADING ON THE CONTINENTAL SHELF

Aim

To simulate the effect of loading on the continental shelf

Preparation

The apparatus for this demonstration can be built in any manual training shop from the working drawings supplied in Figures 1 and 2. The recommended dimensions may be changed within reasonable limits.

Cover the bottom of the trough with gelatin made with half the recommended amount of water. A 2″ layer of light cup grease is desirable, but gelatin is cheaper and more easily obtained. Cover the layer of gelatin with plastic wrap so that the edge of this film comes up to the top of the sides and ends of the trough. Pour a layer of sand on top of the film, making the total contents about an inch thick. At the right-hand end, add about a pound of No. 1 shot, which can be purchased at a sporting goods store. Spread the shot on the bottom beginning at the end of the trough and extending for about 12″. Add a 1″ layer of sand on top. Build the sand layer thicker at the left end until you have a profile like the one shown in Figure 2. Gently add water to the trough until it reaches the level shown in the figure. Continue to add water as it percolates into the sand. It may take 15–20 minutes to saturate the sand. This preparation should be completed before making the demonstration.

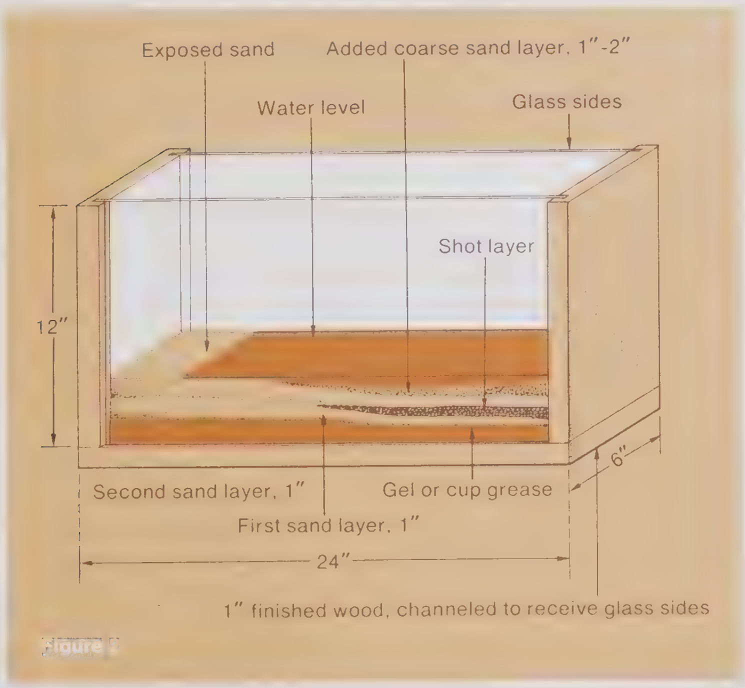


Figure 2

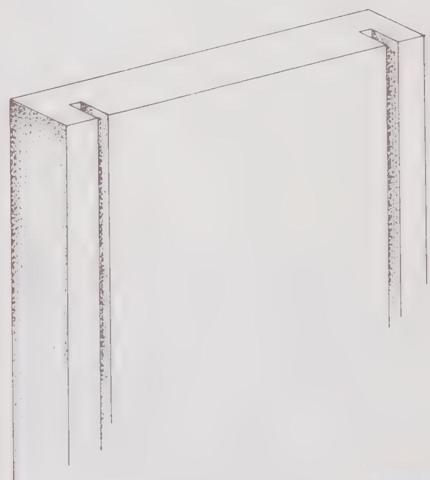


Figure 1

1″ x 6″ x 12″ finished pine (2 pieces)
1″ x 6″ x 24″ finished pine (1 piece)
23½″ x 12″ window glass (2 pieces)
Make ½″ deep rabbets to hold glass on top and bottom pieces. Cement the glass into the grooves with putty. Screw the end pieces firmly to the bottom.

Demonstration

First, explain to the class that the apparatus represents a model of the cross section of the edge of a continent. Some of the land and the continental shelf are apparent. Second, explain that you are going to try to demonstrate what happens as the continental shelf is loaded with sandy sediments. Point out that the gelatinous material at the bottom represents the plastic layer in the earth's crust. Explain that the loading of the continental shelf takes place slowly and that the model does not contain enough continent to supply the sediments.

Third, add about an inch depth of coarse sand to the continental shelf area of the model. Call attention to the slight depression of the plastic layer under the shelf. Add more coarse sand to the shelf. Call attention to further depression of the plastic layer under the shelf and the slight uplift as represented by the thickening of the plastic layer under the continent.

Fourth, point out that the action that has been simulated takes place in nature over millions of years, not in the few minutes that were devoted to the demonstration.

With a long-handled kitchen spoon, remove the sand that was added during the demonstration to restore the balance. You are then ready for the next class.

Teacher's Demonstration:

WAVE MOTION

Preparation

Most physics departments now use a wave-generator and ripple tank originally designed for PSSC courses. You will find this device very useful in demonstrating what happens to waves as they meet various obstructions. The machine should be set up in such a manner that all pupils have a clear view of the ceiling above the ripple tank if illumination comes from below or so that they can gather around and watch the display if the light is above the tank.

The submerged barriers should be cast of paraffin and loaded with lead shot or nails while semimolten. The other barriers should be made of hardwood, 1″ x 2″ stock, cut to the proper lengths. They may be finished with spray-on varnish or enamel paint. They work best when the surfaces are as smooth as possible.

Models of particular shorelines can be fashioned of paraffin and placed at the far end of the tank for study of wave patterns.

The authors have found that the standard ripple tank (Hubbard 2401), while satisfactory, is a little small for complicated earth science demonstrations. For these, a tank 2 feet by 4 feet or even 6 feet is more satisfactory. It can be built in any school shop. Be sure that the glass used for the bottom is either very heavy windowpane or light plate glass.

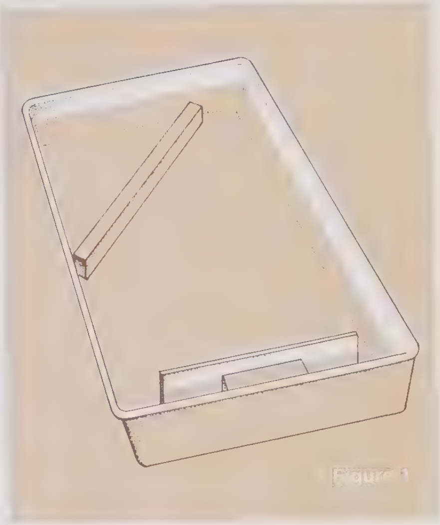


Figure 1

Demonstration

Simple reflection Operate the wave-generator at low speed and watch the wave front being thrown back or reflected as it meets the opposite end of the tank. The reflected waves may phase with the direct wave and reinforce the oncoming wave, or they may be wholly out of phase and essentially cancel the oncoming wave. This depends upon the velocity and wavelength of the generated waves, and can be controlled by varying the speed of the wave-generator.

Reflection at an angle Place a barrier at the side opposite the wave-generator and at 45° to the direction of wave travel, as shown in Figure 1. The reflected waves will move away from the barrier at 90° to the oncoming waves and will form a dappled interference pattern. A little chalk dust or talcum powder sprinkled on the surface of the water will show that a longshore current is set up.

Refraction Place a short barrier about midtank, with its long face parallel with the generated wave front, as shown in Figure 2. A concentric pattern of refracted waves will be seen rounding the ends of the barrier and disturbing the water surface that is shielded from direct waves.

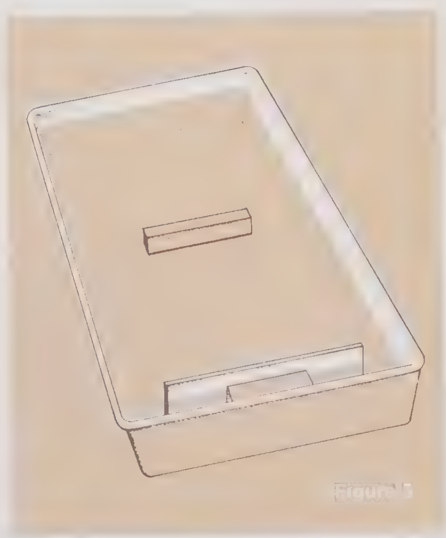
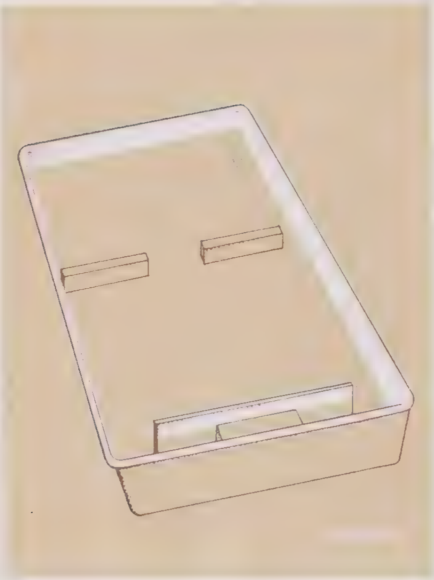


Figure 2

Effect of wavelength on refraction Use the same setup and vary the frequency with which the waves are formed by speed-

ing or slowing the wave-generator. The high-frequency waves with short wavelengths will be refracted more than the waves with longer wavelengths.

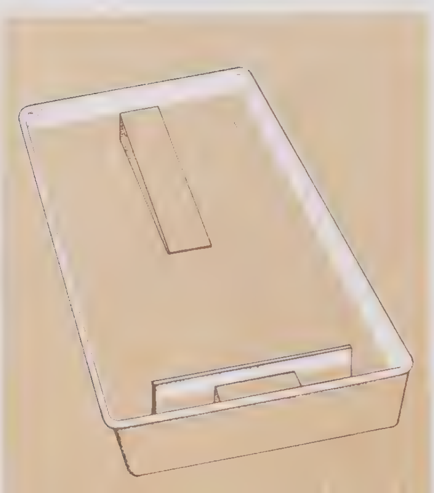


Inlet effect Place two barriers across the midsection of the tank so that the outer ends are in contact with the outer walls of the tank and the inner ends are 2″ or 3″ apart. (See Figure 3.) Waves will be produced in the protected "lagoon" behind the barriers, and will spread throughout the protected area radiating from the inlet.

Focusing effect of a submerged ridge Place a wedge-shaped block such as that shown in Figure 5 at the end opposite the wave-generator, with the thin end of the wedge toward the generator and the thick end against the far wall. (See Figure 4.) This obstacle will refract the waves and they will be reinforced as they pass over the obstacle.

Shoaling water off a beach In the far end of the ripple tank, place a sloping board or piece of glass to represent shoaling water off a beach. Set this at an angle to the direction in which the waves travel. Use a low speed on the wave-generator. The incoming waves will refract and turn toward the "beach."

The only limit to the number of demonstrations possible with a wave-generator and ripple tank is the ingenuity of the demonstrator. The above seven cover the principal demonstrations needed to illustrate the text.



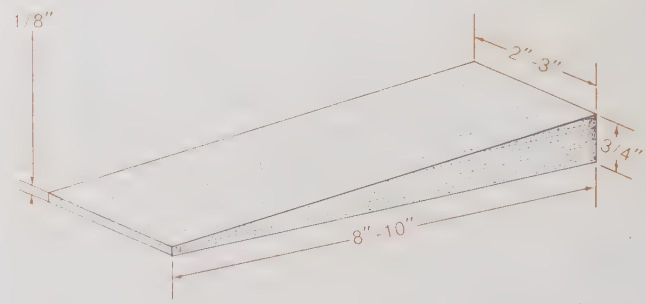


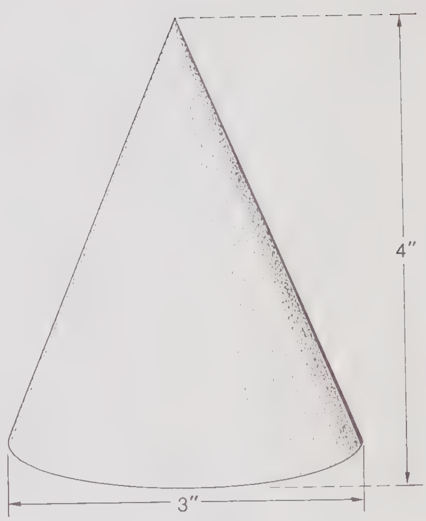
Figure 5

SIMULATING VOLCANO

It is possible to produce a convincing minature volcano as a teacher demonstration. The effect is caused by burning ammonium dichromate. The reaction produces enough hot gases to eject the voluminous fluffy chromic oxide that is produced. The demonstration may be made simple or elaborate depending upon how much time you wish to devote to preparation. The simplest demonstration is to heap about 2 ounces (50-60 grams) ammonium dichromate on a thick asbestos sheet. Use a fuse of magnesium tape, about 2″ long, to ignite the dichromate. As it burns, it will throw up deep-green-colored chromic oxide ("scoria") and a few sparks. The "scoria" will fall back and build a cinder cone.

For a slightly more elaborate demonstration you can make a model in plaster of paris of a small volcano with a crater about 1″ in diameter and a cross section like that shown in Figure 1. Place the model on an asbestos sheet, and charge and fire it. A sand table with a 2″ layer of sand may be used instead of the asbestos sheet.

With a little ingenuity you can design such an elaborate demonstration that it will seem as if a crevasse appears in a "field" and a cinder cone similar to Parícutin will develop. The larger the charge, the longer the volcano will erupt. The charge of ammonium dichromate may be increased to as much as 8 ounces (250 grams.)



Make a cone of heavy manila-folder paper.

Coat the cone with thick plaster of paris in a layer ¾″–1″ thick. When dry (2–3 days), cut the tip off the paper cone. Charge and use.

Introduction To Reading And Interpreting Topographic Maps And Stereoscopic Aerial Photographs

The following four exercises have been selected from the Silver Burdett manuals *Topographic Maps for Earth Science* and *Stereoscopic Aerial Photographs for Earth Science.* These exercises were chosen for presentation here because they are representative samples and are an appropriate introduction for students who are not familiar with the reading and interpretation of such maps and photographs. Answers to the questions posed in these sample exercises may be found on page 169.

Information obtained from the correct interpretation of topographic maps and stereoscopic photographs is an integral part of the study of earth science. Therefore, these two exercise manuals, which give students practice in the skills of reading and interpreting maps and photographs, have been incorporated in the SILVER BURDETT EARTH SCIENCE PROGRAM. It is recommended that if time and student interest warrant, the whole of the two manuals be undertaken for study.

The exercises are certain to increase the students' understanding of and interest in the study of earth science. The maps and photographs cover a wide geographic range and include an extensive and interesting array of geologic formations. Procedural instructions are self-explanatory within each exercise.

27 DISSECTED DOME

AREA: LITTLE DOME, WYOMING

In the sparsely vegetated hills of the West, earth structures are often exposed in such detail as to look like a model. Such is Little Dome. Since this dome is elongated, the pattern of upended sediments dipping away from the center resembles a pitching anticline, as shown in Exercise 25. However, a dome is clearly formed by being pushed up from underneath. Once a dome has been stripped by erosion, it may show the core of a once-molten rock or even a column of salt that did the pushing.

A. The core rock at *A* does not seem to be exposed. The rock at the center looks much like the overlying sediments. Unless there is an erosion-resistant igneous core exposed, the hollowing-out of the center as shown here is typical. This hollowing may have resulted because weaker sediments have been exposed. In what other way could the layers at the center of the dome have been weakened by the push from below? They would have been stretched, and the tension cracks formed in them would speed the break down.

1. What do you think would be the rock types of the ridges and valleys here?

B. If material is to be carried away from (almost quarried out of) the center of the dome, there must be a well-formed drainage system to carry it.

2. What would have been the patterns of the first streams flowing off the dome?

As erosion progresses, the tributaries carve their channels into the weaker rock layers, gradually etching out a pattern of concentric circles of alternately weak and strong layers as at *B* and *B′*. This ringlike system is called an annular drainage pattern. A weak layer may develop a broad, flat, oval valley called a race track.

3. Where is the racetrack here?

In time one or more of the original streams becomes the master stream, whose tributaries may almost encircle the whole dome.

4. Which is the master stream here?
5. Notice that the two streams flowing at the ends of the dome, *C* and *C′*, no longer drain the racetrack. Where do these streams drain?
6. What does interior drainage, as noted above, indicate about the climate?
7. What do the playas and the dammed-up pond near *A* indicate about the rock composing the racetrack?

Note that the smallest secondary streams have etched out triangular slabs in the tilted layers. These are called flatirons because of their shape. (See also Exercise 23.)

C. Exercise 25 described rock layers dipping into the ground. A geologist not only measures the angle at which layers dip into the ground, but he also maps the compass direction taken by the edge of an outcrop of rock. For example, the upended rock layers, or hogbacks, at *B* and *B′* dip down to the right, but their exposed edges run, or strike, from lower left to upper right. A geologist would map them, using a dip-and-strike symbol as marked on the diagrams, in which the arrow indicates the direction of the dip, and the straight line at right angles to it indicates the direction the edge of the outcrops runs, or strikes.

31 METEOR CRATERS ON THE MOON

AREA: GOCLENIUS CRATER, SEA OF FERTILITY

Our final stereoscopic aerial photographs were taken from Apollo 8 as it orbited the moon on the first round-trip flight, at the end of December 1968. Due to previous photomapping, Apollo 8 and following flights were furnished with detailed navigational charts of this unknown terrain. The chart produced from the Apollo 10 flight includes the predetermined flight path for Apollo 11, photographic data, checkpoints, and the location of an earlier Surveyor landing, as well as the proposed landing site of Apollo 11's Eagle in the Sea of Fertility.

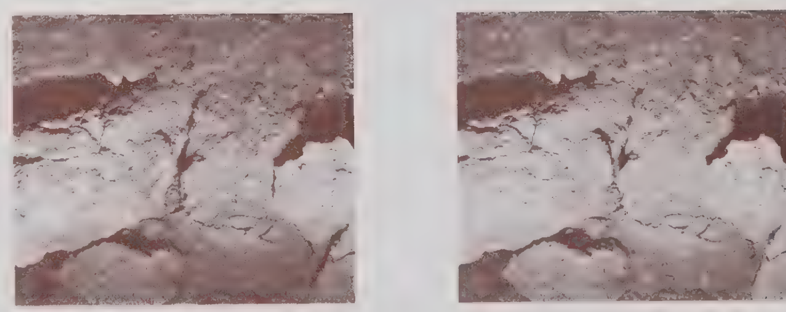
A. Note that this pair of photographs was taken at an angle to the lunar surface rather than straight down. The low position of the sun (about 12 degrees above the lunar horizon) brings out the relief of the crater walls.

1. Would you say that the three craters left of center are older, or younger, than Goclenius? Why?
2. Since there is no atmosphere that would produce stream or wind erosion, what process might have softened the contours of Goclenius?
3. In what other exercise have you seen active slumping?
4. Would moonquakes hasten the slumping process?

B. Examine the lines crossing Goclenius crater. Selenologists, scientists who study the moon, call these lines rilles. However, on Earth, rills are erosional features.

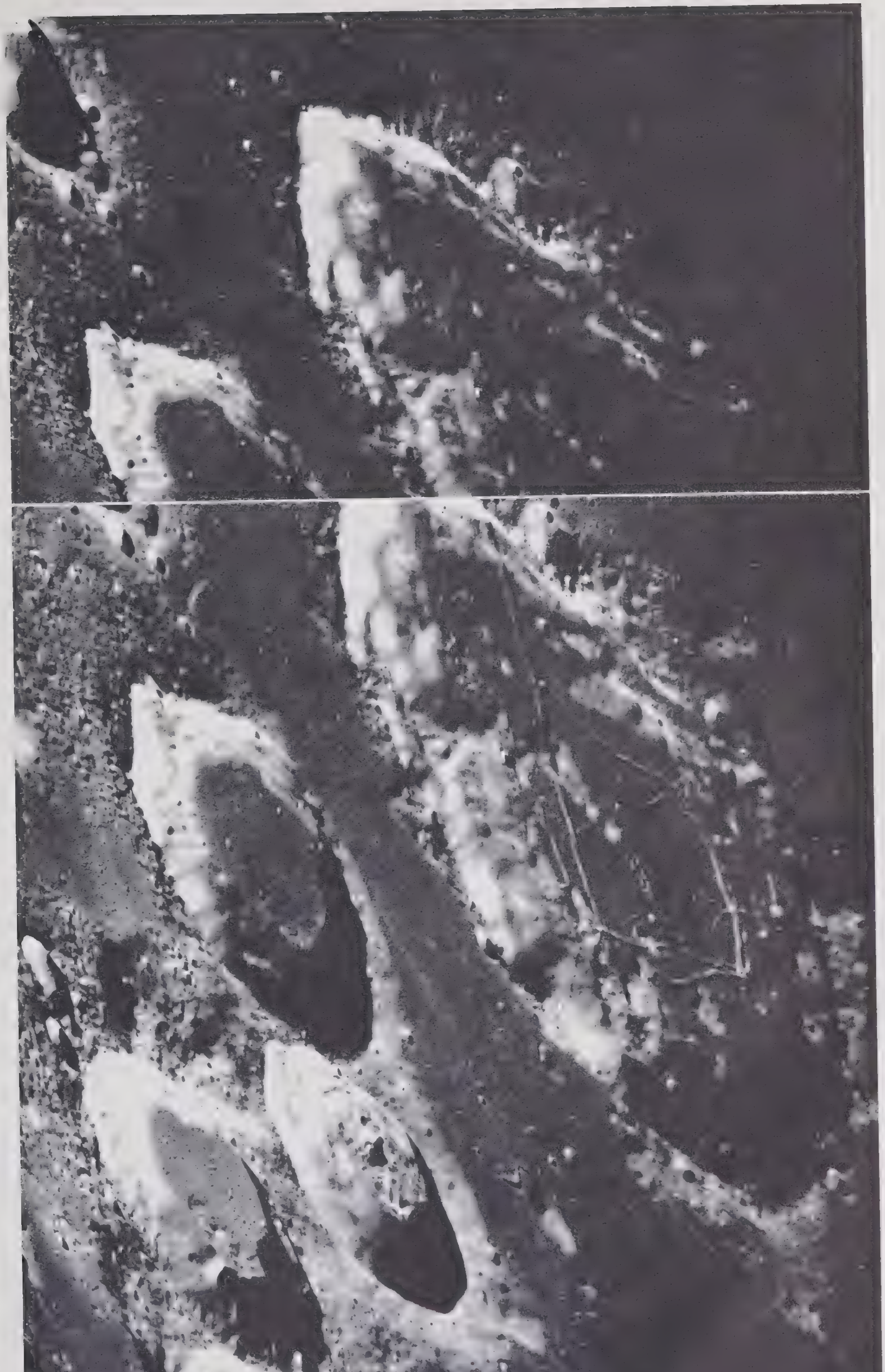
5. Why are lunar rilles probably not due to erosion?
6. What earth feature does the long rille across Goclenius most resemble? Why?
7. Would you say that the crater had been formed before, or after, the rilles? Why?
8. If the rilles are fault lines, what do they tell us about the "dead crust of the moon"?

To help answer the above and other questions, the Apollo 11 astronauts left a seismometer on the moon to record moonquakes.

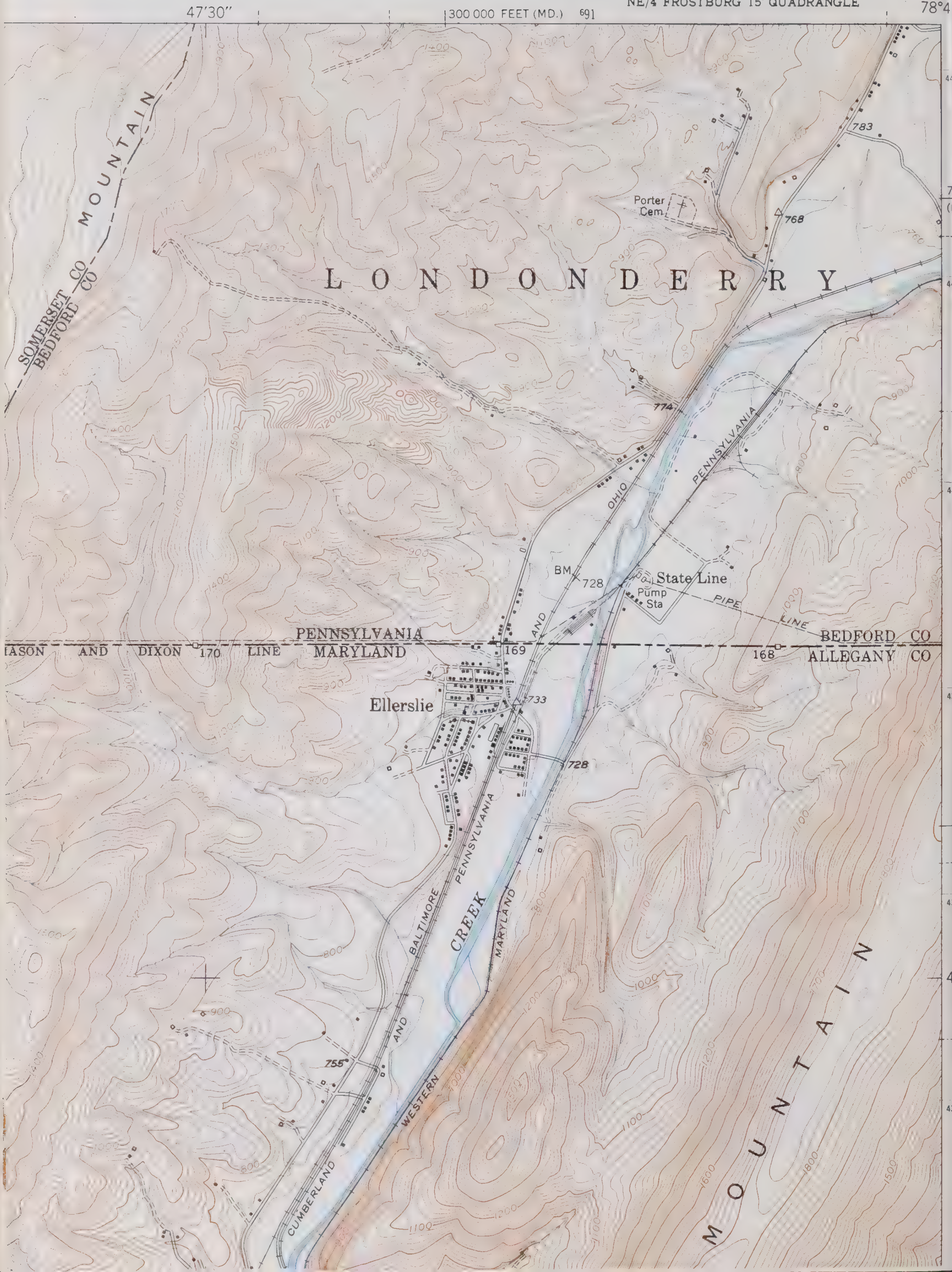


LUNAR ROCKS

A stereoscopic closeup view showing a clump of lunar surface material. Many small, shiny particles can be seen in this area of lunar surface that is three inches across. The exposure was made by the Apollo 11 35-mm stereo closeup camera. The camera is mounted on a walking stick, and the astronauts used it by holding it up against the object to be photographed and pulling the trigger on the walking stick.



CUMBERLAND QUADRANGLE
MARYLAND-PENNSYLVANIA-WEST VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
NE/4 FROSTBURG 15' QUADRANGLE



Map: Cumberland, Md.–Pa.–W. Va.
Contour interval: 20 feet
Scale: 1:24,000 (1 in. = 2000 ft.)
Reference: 39°37′30″N, 78°52′30″W

READING A MAP

On the opposite page is the NE corner of a United States Geological Survey topographic map. The upper right corner shows the location of the area included on the entire map. On a U.S.G.S. map, information about who did the mapping and how it was done appears in the lower left corner of each sheet. The scale information is centered at the bottom. You will also find information about the relationship between magnetic (compass) north and true north at the bottom of the map. On U.S.G.S. maps, true north is always in the direction of the top of the sheet.

A. At the corners and along the border lines of the map you will find the geographic coordinates. The geographic coordinates in the SW corner of a map are the reference for the map.

1. What are the latitude and longitude of the NE corner of the map?
2. This quadrangle is 7.5 minutes square. What designation of longitude and latitude would you find in the SW corner?
3. Notice that there is a large black cross (+)in the lower left portion of the map. This marks the intersection of what lines of longitude and latitude?

B. The brown lines on the map are called contour lines. Each line connects all the points that are at the same elevation above sea level. Notice that each fifth line is heavier than the others. Also notice that on this map each of these heavier lines is labeled with a number that is an even multiple of 100.

4. What change in elevation does each of the finer lines indicate?

In the SE corner of the map, there is a narrow region where the contour lines are relatively far apart. On both sides of this region, and more or less parallel with it, the contour lines are closer together. Notice how the contour lines are numbered. This is the way a mountain ridge is represented by contour lines.

5. What is the elevation of the high point of this ridge?
6. What is the elevation of the valley around Ellerslie?
7. How high above the valley is the high point of the ridge?
8. Examine the contour lines on the west side of the ridge. Are they closer together above or below the 1200-foot contour line?
9. What does your answer to Item 8 suggest to you about the steepness of the slope?
10. Test your answer to Item 9 this way: Measure the distance between the 1200- and 1400-foot contour lines. It is 0.25 inch. The scale of the map is 1:24,000. How many feet does 0.25 inch represent?
11. By dividing the change in elevation (200 feet) by the number of hundred (5) horizontal feet, you arrive at the gradient per 100 feet. What is the gradient in the area measured in Item **10**?
12. Now determine the gradient per 100 feet between the 1000- and 1200-foot contour lines. What is it?
13. State a general rule that you can use to relate contour lines to the gradient of a slope.

C. In the NW part of the map, there is a house. It is high on the mountain and all alone. A road leads to this house.

14. How far in a direct line is this house from its nearest neighbor?
15. How high above its neighbor is this house?
16. What is the straight-line gradient between the two houses?
17. Most automobiles have difficulty climbing a rough, unpaved road with 12% grade of slope (12-foot climb per 100 feet). Would it be easy to drive to the house high on the mountain?

D. Measures of the gradient of land slopes usually are given in feet per 100 feet. Major streams usually have such low gradients that it is usual to state the gradient of a stream in feet per mile. Wills Creek is the stream that flows by Ellerslie. Close to the southern edge of the map you see a contour line that crosses Wills Creek. Follow the creek north until you find the next place a contour line crosses it.

18. How much has the stream changed in elevation between these contour lines?
19. What is the map distance along the creek between the lines?
20. What is the gradient per 100 feet?
21. What is an easy way to convert your answer for Item **20** to a per-mile gradient?
22. What is the per-mile gradient of the stream?

ESTERO
BAY
Morro Beach
Water Tank
Oil Tanks
BM 36
BM 121
PIPE LINE
Gravel Pit
Morro Creek
Little Morro
Water Tank
584
717
868
1185
569
505
755
656
707
470
781
SAN BERNARDO (CANE)
San Bernardo Spring
Pillar Rock
Morro Rock (STATE PARK)
581
Beacon
Breakwater
Morro Bay
BM 34
BM 150
Water Tank
BM 22
516
Black Hill
665
MORRO BAY
STATE PARK
Chorro
Banning Sch
Quintana Cem
BM 129
BM 24
912
Fairbank Pt
White Pt
Park Ridge
802
Hollister Peak
1404
MORRO BAY
MORRO BAY STATE PARK
62
81
79
614
BM 14
Water Tank
Windmill
BM 263
23
Baywood Park
Creek
Gravel Pit
539
Gravel Pit
Eto Lake
Windmill
Warden Lake
Cuesta-By-The-Sea
BM 99
CAÑADA DE LOS OSOS Y LOS OSOS
Sunnyside Sch
BM 90
Water Tank
Reservoir
Windmill
Los Osos
402
Los Osos Sch
450
PRIVATE
BM 234
1001
Hazard Canyon
705
595
PECHO Y ISLAY
1123
653
JEEP TRAIL
1101
1105
Clark Valley
Prospect
SAN LUIS RANGE
1321
1219
Springs
1095
BM 37
Water Tanks
1359
Islay
1216
1453
Valencia Peak
1345
1295
1425
1285
BM 19

Map: Cayucos, Calif.
Contour interval: 50 feet
Scale: 1:62,500 (1 in. = 5208 ft.)
Reference: 35°18′N, 120°52′W

MAKING AN OVERLAY

OFTEN WHEN you are working with maps you want to examine some particular relationship between features. Sometimes it is convenient to use an overlay for this. As you will see, the advantage of using an overlay is that you can eliminate all the details on the map except those you need for your study. Here is an example of the preparation of an overlay and one way that an overlay can be used. You may find overlays useful in other map exercises that do not call for them. There is nothing that says you must not make an overlay!

A. The scientists who are studying the great masses of ice in the polar regions state that if all of it melted, sea level would rise about 125 feet.

1. What effect would this have upon the country shown on the map?
2. What is the contour interval of this map?
3. Where would the new shoreline be?
4. Is there a 125-foot contour line marked on the map?
5. Where would you locate the approximate position of the 125-foot contour line?

B. The best way to get a good idea of the effect of a 125-foot rise in sea level is to prepare an overlay that shows only the present shoreline and the 125-foot contour line. Then all the area between the two represents land that would be submerged.

Place a piece of tracing paper over the map. Register this by marking three points on the paper with a sharp, soft pencil. Use BM 19 (bench mark 19) in the SW corner of the map, BM 36 near the oil tanks north of Morro Beach, and the triangulation point 1404 on the summit of Hollister Peak near the eastern margin of the map. This is done so that you can always place the overlay as you now have it, should the overlay slip while you are working on it.

Keeping your overlay registered, carefully trace the present shoreline. Be careful that you do not press so hard with your pencil that you make an impression on the map. Now you are ready to trace the future shoreline on your overlay. Be sure that your three register marks are over the points that they represent on the map. Carefully draw a line that lies about halfway between the 100-foot contour line and the 150-foot contour line. Again, take care that you do not press too hard with your pencil. Now remove your overlay from the map for the rest of the exercise.

C. Study your overlay and the map.

6. In which general area is there the least distance between the present shoreline and the future one?
7. In which area is there the greatest difference between the two shorelines?
8. What happens to the new shoreline at each stream?
9. What would happen to Morro Rock if the polar ice melted?
10. Would any new islands be formed if the polar ice melted?

D. The action of waves and currents in the past few thousand years (very recently in terms of geologic time) has moved sand along the coast. This action has tied Morro Rock to the land and built the beach that is now named Morro Bay State Park. In large part, the location of the barrier beach that cuts Morro Bay off from the ocean is determined by the headland of the San Luis Range.

11. Describe what we might expect to see in this region five or six thousand years after the new shoreline is established.
12. What do the sand bars in Morro Bay and the marshes in the eastern part of it suggest is happening there?
13. What would you expect to happen to Morro Bay after the new shoreline is established?
14. Predict what kind of shoreline will eventually be established.

EXERCISE ANSWERS

TOPOGRAPHIC MAP EXERCISE 1

1. 78°45′W and 39°45′N. **2.** 78°52′30″W and 39°37′30″N. **3.** 78°47′30″W and 39°42′30″N. **4.** 20-foot change in elevation. **5.** About 1900 ft. **6.** About 730 ft. **7.** 1900 − 730 = 1170 ft. **8.** Above the 1200-foot contour line. **9.** The slope is steeper above 1200 ft. than below it. **10.** 1 in. = 24,000 in. = 2000 ft. Therefore, 0.25 in. = 500 ft. **11.** 40 ft. per 100 ft. **12.** The gradient will measure 18 to 28 ft. per 100 ft., depending upon where it is measured. **13.** The closer together the contour lines, the steeper the slope. **14.** 4550 ft. **15.** 1700 − 970 = 730 ft. **16.** 730/45.5 = 16 ft. per 100 ft. **17.** No, the grade is steeper than 12% and the road is unpaved and probably rough. **18.** 20 ft. **19.** About 6.9 in. **20.** 0.146 to 0.143, depending upon the distance measured on the map. **21.** Multiply by 52.8, the number of 100-foot units in a mile. **22.** 7.8 to 7.5 ft. per mile.

TOPOGRAPHIC MAP EXERCISE 4

1. Part of the land would become ocean bottom. **2.** 50 ft. **3.** The new shoreline would be where the 125-foot contour line now is. **4.** No. **5.** Halfway between the 100- and the 150-foot contour lines. **6.** In the SW portion. **7.** Around Morro Bay and especially in Canada de los Osos. **8.** It extends farther inland along streams then elsewhere. **9.** It would become an island. **10.** In addition to Morro Rock becoming an island, a small island would be formed just east of the Gravel Pit that is east of Baywood Park, and there may be a tiny islet SW of Hill 802 of Park Ridge. **11.** The waves and current probably would build a new barrier beach about where the present one is or a little more inland, and possibly Morro Rock would again be tied to the land. **12.** Alluvium from the streams is filling in Morro Bay. **13.** The drowned stream valleys would fill with marshes, and in time the bay too would be filled and disappear. **14.** A smoothly curved shoreline similar to the one that now exists.

STEREOSCOPIC AERIAL PHOTOGRAPHIC EXERCISE 27

1. Probably resistant sandstone ridges, or possibly limestone in this dry climate; weak shale in the valleys. **2.** Radial, or away from the high center. In an elongated dome one could expect four streams. **3.** The second main ring from center, with streams *B-B′* and *C-C′*. **4.** The one at right, *A-A′*. **5.** Into two small playa lakes, one near each end. **6.** It is dry. **7.** It is probably shale, since it appears to hold water.

STEREOSCOPIC AERIAL PHOTOGRAPHIC EXERCISE 31

1. The craters are younger because they are more clear-cut and therefore fresher. The walls of Goclenius appear more worn down. **2.** Mass wasting, or slumping, due to gravity. **3.** In Exercise 24 (Surface Effects of Faulting). **4.** Yes. **5.** They are not due to erosion because they do not appear to drain a slope. Also, the long rille crosses over the rim of the crater. **6.** It resembles a fault line because it is straight and crosses the rim of the crater. **7.** It had been formed before the fault appeared because the crater explosion would have erased the line if it had occurred afterward. **8.** If the rilles are fault lines, it means that the lunar crust is active.

Maps were one of man's earliest devices for communicating and preserving knowledge. Primitive people who had not yet developed a written language had usually developed the idea of communication by maps. This is particularly evident in our own Southwest, where pictographic maps were pecked into the rock of canyon walls. These maps trace routes from one place to another, showing the location of water and the length of the journey. The information on any map, prehistoric or modern, is communicated by a series of symbols. This is no different from a printed page, where combinations of the 26 symbols of the alphabet are used to communicate and preserve our knowledge and thoughts. The ability to read a map is easily developed and should be included in every person's educational background.

There are a great variety of maps—contour maps, weather maps, maps showing altitude in hundreds of feet, population-density maps, rainfall maps, and geographic maps. In many of these categories there is a wide diversity in the amount of detail shown. For instance, the schematic maps often found in railroad or airline timetables distort the truth, giving the impression that the transport system involved follows a shorter route than does its competitor. At the other extreme are the very precise topographic maps prepared by such national agencies as the United States Geological Survey and the Army Map Service. The symbols used on topographic maps are used almost universally. As a result, except for the place names, a foreign topographic map is as readable as one published in English.

This book of exercises in topographic map reading provides the earth science teacher with a compact and convenient set of maps for use as a teaching aid. Each of the maps is accompanied by a carefully programmed exercise. Answers are included at the end of this book. Not all teachers feel sufficiently adept with topographic maps to use them as a teaching tool. This book has been prepared so it may be used by any teacher, whether an expert or an amateur at map reading.

This book could not have been prepared without the full cooperation of the United States Geological Survey, who allowed reprinting from their original plates. The authors have tried to select topographic sheets that are included in the current edition of *A Set of One Hundred Topographic Maps*, prepared by the U.S.G.S., because many schools own this set of maps. The plan for each exercise follows a pattern. An opening paragraph establishes the locale of the area depicted. It is followed by two or three sections of questions. All the exercises contained in the book can be used successfully with students of all ranges of academic ability. Depending on the abilities of the students, the teacher will soon discover the optimum rate at which to proceed through these exercises. Fast students will require a minimum of supervision, while slower students may require

ample discussion geared to each question. In schools where the students do not own their textbooks, be sure that the students answer the questions on a separate piece of paper. Their answers should be properly labeled with the question number, for easy marking. When students make tracings, it is best to have them use soft (No. 2) pencils and to press lightly so as not to make an indentation on the surface of the map. Felt-tipped pens are satisfactory, but ball-point and fountain pens are not.

The thirty exercises that are presented in this book cover many facets of geomorphology, the study of landscapes. The sequence of the exercises correlates reasonably with that of the textbook. However, map reading is not applicable to every chapter, so only those topics that are best illustrated by maps have been treated. The authors have selected material that is most easily comprehensible to the beginning student in earth science and map reading. Many features that are obvious to the expert are totally invisible to the beginner. The included exercises have all been tested and refined by use in classrooms.

You can devise additional exercises based upon the maps in this book; the authors have by no means exhausted the teaching possibilities. In addition, it is recommended that where funds are available you purchase selected local maps for additional exercises. The current price is about $18 per set of 30 copies of a single sheet. It is highly recommended that you obtain maps of the quadrangle in which your school is located. Your students are familiar with that area and can see the relationship between the configuration of the land and its map presentation. This local map should be used immediately following Map Exercise 1.

The book of maps should be used for reference while studying the text. To help you find the maps best suited to a particular topic, a list of physiographic features and the maps on which these features are clearly indicated is included. Features may be located on a map in either of two ways. The standard method of describing the location of a specific plot of land over the major portion of the United States is with reference to U.S. Land Office township grids. This grid is present on many of our maps. Map Exercise 3 is specifically designed for teaching how to use the township grid. On maps lacking this grid, a modification of the "atlas grid" is used. This is a combination of letters and numbers that is commonly used to locate features on atlas maps and many others. The authors have divided the map into nine imaginary rectangles, three tiers of three. From left to right these are numbered 1, 2, 3; and from top to bottom, lettered A, B, C. Thus, each rectangle has a distinctive designation, such as A-1, A-2, A-3 for the tier across the top and A-1, B-1, C-1 for the tier down the left side.

You will need the following supplies for doing the map exercises.

Graph paper. The minimum amount for a class of 35 for all the exercises calling for graph paper is 100 8½"x11" sheets of 10x10-to-the-inch grid. Each sheet should be divided in half lengthwise. Drafting supply companies carry this paper in padded blocks.

Tracing paper. The minimum amount for a class of 35 for all the exercises calling for tracing paper is 400 8½"x11" sheets. Various grades of tracing paper are available.

Map-measurers. Drafting supply companies usually stock map-measurers. The minimum cost is about $2.50 per instrument. 20-gauge bare copper wire cut into 12" pieces is excellent for measuring lengths of streams. Any hardware shop will carry this. The best type of thread for measuring the length of streams is nylon casting line. This is available at any sporting goods store.

Scales (rulers). The authors suggest using a plastic scale graduated in 0.1-inch intervals and 10" or 12" long. With such a scale, the arithmetic necessary to transpose map distances to ground distances is easy. A scale graduated in the usual 1/16-inch intervals is satisfactory but involves multiplication by fractions, or conversion of the fraction into a decimal of an inch. Here is a table of conversion:

1/16 = 0.0625	9/16 = 0.5625
1/8 = 0.1250	5/8 = 0.6250
3/16 = 0.1875	11/16 = 0.6875
1/4 = 0.2500	3/4 = 0.7500
5/16 = 0.3125	13/16 = 0.8125
3/8 = 0.3750	7/8 = 0.8750
7/16 = 0.4375	15/16 = 0.9375
1/2 = 0.5000	

How and Where to Purchase U.S.G.S. Topographic Sheets

The United States Geological Survey prepares up-to-date state index sheets of the topographic quadrangles. These may be had free of charge directly from either of the two distribution centers named below. On the back of each of these indices you will find a list of other maps sold by the Survey that relate to the state in question. From the index sheet, select the quadrangles that you want and order them by name and scale. Currently, a 20% discount is allowed on purchases of $20 or more and a 40% discount on orders of $100 or more. Send with your order the exact amount necessary to pay for it. There are no handling

or postage charges. Some book shops and stationery stores stock a limited number of local maps. Do not expect discounts from these stores. The most satisfactory method is to order maps directly from the U.S.G.S.

Regardless of where you live, order maps east of the Mississippi River from the Map Distribution Center, United States Geological Survey, Washington, D.C. 20242. Order maps west of the Mississippi River from the Map Distribution Center, United States Geological Survey, Federal Center, Denver, Colorado 80225. Certain U.S.G.S. offices in several states sell maps of the area over the counter. They *do not* handle mail orders, nor do they stock maps other than those of the region covered from the office. In Alaska, mail orders for Alaskan maps will be filled by the United States Geological Survey, 520 Illinois Street, Fairbanks, Alaska.

In addition to the regular topographic sheets, three-dimensional plastic sheets of the 1:250,000-scale maps, printed in color, are available from the U.S.G.S. These are superb visual aids to use for teaching map reading, especially for the interpretation of contours.

Physiographic Features of the Maps

The following list of physiographic features has been prepared to help you select a map from the collection to illustrate a particular point or to compose an exercise of your own.

Coastal Features

Barrier beaches: Exercises 4, 25, 26, 27, 28
Bays: Exercises 4, 25, 26, 27, 28, 29
Bay-mouth bar: Exercise 28
Beaches: All maps showing the coastline, except Exercise 30
Capes: Exercises 25, 27
Deltas: Exercises 4, 8, 25
Drowned coast: Exercises 29, 30
Embayed coast: Exercise 25
Emergent coast: Exercise 2
Fjords: Exercises 11, 30
Hooks: Exercises 25, 29
Lagoons: Exercises 4, 26, 27, 28
Marine terraces: Exercise 2
Sand spits: Exercises 25, 27, 28, 29
Sea cliff: Exercise 27
Sea stacks: Exercises 2, 27
Submarine topography: Exercises 29, 30
Tombolos: Exercises 4, 29
Wave-cut cliffs: Exercises 2, 4, 27

Alpine Glaciation

Continental Glaciation

Mountain Features

Plateau Features

Valley Features

Volcanic Features

Water Features (nonmarine)

Streams are shown on every map used. On some maps, especially those from the western states, there are intermittent streams (and lakes) as well as permanent streams.

Wind Features

Exercise 1

Reading a Map

Maps are used in many ways by many people. Probably the largest group of producers and consumers of maps are earth scientists and military organizations. Both these groups are vitally interested in accurate configuration of the earth's surface, but for different reasons. The military is interested in the utilization of the terrain; the earth scientist, in the interpretation of the terrain. The topographic map is the most important type of map for both these groups. It is a map that combines planimetric distribution of features with various methods of depicting relief.

Of all the methods for showing relief, the most successful and flexible is contour lining. This process was invented by cartographers of the Corps of Topographical Engineers of the United States Army in the middle of the 19th century. Its first important use was in publications of the *Survey of the United States West of the 100th Meridian*, during the 1870's. This method uses a line that connects all points of identical elevation above sea level, the contour line. A series of these lines, methodically spaced, reveals the form of the structure being depicted. These lines can be likened to the position of the shoreline if sea level were raised to the elevation represented by the line.

The Contour Model Kit devised by Hubbard Scientific Co. and distributed by several school supply companies is an excellent device for demonstrating the theory behind contour lining. Any of the plastic relief maps available from A. J. Nystrom and Company, Chicago, Ill., are fine classroom exhibits. These are based upon U.S.G.S. quadrangles, and the exhibition of the two, one beside the other, will be revealing to your students.

We strongly recommend that this exercise be accompanied or followed by class study of the full U.S.G.S. topographic map of the area in which your school is located. These can be procured in quantity from the Map Distribution office of the U.S.G.S.

The technique of measuring distances on a map must be taught in this exercise. The measurement should be made in inches, and decimals of an inch. The metric system can be used, but since the maps are made with contours in feet, the metric system entails conversion of elevations from feet to meters. To do so is pedantic nonsense. As a nation we use the inch, foot, and mile. The ideal measuring scale is divided into 0.01-inch units, but such scales are expensive.

Straight-line distances are easily measured and need no teaching. Distances along streams or winding roads are difficult to measure accurately. The ideal instrument for this is a map-measurer (a miniature odometer). These are expensive, but easy to use and very accurate. A piece of soft copper wire bent to follow a line being measured, then straightened for measuring, can be used, but it is difficult to manipulate. A piece of

thread can be similarly used and measured a little more easily, but requires more careful manipulation than you can expect of most eighth- or ninth-grade students. A pair of dividers that can be set to a specific unit of distance can be used to "pace off" the distance along an irregular line with considerable accuracy. The measurement will always be a little short of the true distance. A simple procedure is to twist and turn the straight edge of a piece of paper along the line to be measured, using a pencil point as a pivot at each turning point. This method, too, will yield a distance that is a little short. It is tedious, time-consuming work but requires no special materials, and students do become adept at it. The accuracy of the final measurement along the edge of the paper slip depends upon careful selection of turning points, and prevention of unintentional slipping of the paper.

Exercise 2

Profiles and Gradients

The construction of a profile is an operation that requires care and thought. In preparation for this exercise, a grid of lines representing a piece of graph paper should be drawn on the blackboard. On this you should demonstrate how to transfer the tick marks from the edge of the paper to the proper line representing the elevation of the contour line being transferred. You may be able to borrow a portable piece of gridded "blackboard cloth" from the math department to use for this purpose. You can make a good demonstration chart for profiling by ruling the required lines, about 2 inches apart, on a piece of white oilcloth. Paint the lines with black casein or oil paint. This will produce a washable chart. Draw on it with a black grease pencil, the mark of which can be removed with a cloth wet with lighter fluid. A supply of standard 10 x 10 graph paper will be needed. Two pieces, each 10″ x 4″, will be needed by each student.

This map can be used for another exercise if you wish to discuss coastlines. There is good evidence that the land-sea relationship has changed in the region. The islets, rocks, and sea stacks offshore suggest encroachment by the sea. The old stranded delta, or alluvial fan, of Beal Creek suggests uplift of the land, in relation to the sea, that took place earlier in the earth's history. There is evidence of old beach lines between 80 and 120 feet above sea level (a.s.l.) and possibly between 120 and 160 feet a.s.l. Beal Creek became a tributary of Little River after the uplift. Three of the streams, Big River, Little River, and the unnamed stream between them are depositing deltaic material as evidenced by the sand beaches and sand flats at their mouths.

Exercise 3

The Township Grid

Over the major portion of the United States, the Township System of the United States Land Office Survey is the legal method for describing property. The fact that the geographic

meridians converge to the north required the township grid with its square townships to diverge from the geographic grid of latitude and longitude. This in turn required that certain selected meridians be used as the basis for the township grid. These are called principal meridians, and the 6-mile townships are laid out rectilinearly from these and the true east-west parallels, called baselines.

In order to keep some regularity of the pattern of townships, correction lines are used. Along these you will find odd-shaped sections. There is a correction line on the map we have used. It lies between T8N and T9N. It is apparent from the pattern of sections on the map used that three survey teams were involved: one for the northern half and two for the southern half, with the southern work divided along the boundary between R4E and R5E.

The practice problems that we have included can and should be supplemented by similar problems based on other maps in this book that show the township grid. If you can purchase enough topographic sheets of your area, you should do so, and develop a similar exercise based upon that map.

Exercise 4

Making an Overlay

Overlays are made for any of a variety of reasons when it is desirable to isolate certain map features for study. At other times, overlays are made to add data temporarily to the map, such as rainfall, temperature, and geology, without marking the original map. In many of the exercises in this book, overlays can be used for additional studies originated by the teacher. When you require an overlay to be made, insist upon a uniform set of register marks so you can quickly place the student's work over your solution to the problem, for grading purposes. A good quality, translucent tracing paper must be used so the map will show clearly through the overlay. Several kinds are available that are quite satisfactory.

We recommend that Parts A, B, and C of this exercise be used early in the school year, and that Part D be delayed until your students have studied and discussed shorelines.

Exercise 5

Streams I

The Souris River, in the area shown on the map, is a perfect example of a meandering stream with a low gradient. The Silver Burdett Stereoscopic Aerial Photograph Exercise 8 will be helpful to use with this exercise. The Souris River wanders across the ground moraine of the last continental glaciation. In the 10,000 or so years that the land has been free of ice, the river has developed a floodplain. In the mapped area there are evidences of two earlier floodplain levels, now river terraces. The present floodplain has an average elevation of about 1490 feet a.s.l. Terrace I lies about 1525 to 1530 feet, and terrace II about 1570 feet. On the south side of the present floodplain the escarpments for terraces I and II are the same. The long, slender

lake in section 33 was probably formed during a spring flood that filled an old meander-scar depression at the foot of the escarpment. In time it may be captured by the nearby loop of the river in section 33.

The swell-and-swale topography in sections 15 to 17 at the bottom of the map is characteristic of ground moraine.

Exercise 6

Streams II

One of the characteristic stream patterns in upturned sedimentary rocks is trellis drainage. The example seen on the map for this exercise is a textbook example. Other topographic sheets of the Appalachian Mountain region have equally good examples. In regions of trellis drainage you often find good examples of stream capture. (See Photograph Exercise 9.) The ones that we have indicated in the exercise are, we believe, clear enough for beginners to recognize. There are other examples on this map, but they are less easily noted. There probably have been several captures across Little Mountain.

Although the section of the full U.S.G.S. sheet we have used can be used to study something of the ridge pattern that develops at the end of a peneplained syncline after rejuvenation, the full sheet and adjacent Harrisburg Sheet are much better for an exercise of that nature.

Exercise 7

Streams III

This portion of the Snake River is famous for its display of springs that emerge from under the lava flow and cascade to the river. Just east and also north of the section of this quadrangle are several groups of springs that have been captured, and the water flow is used to drive hydroelectric generators.

The full sheet should be posted while your pupils are doing this exercise. On it the plains character of the lava flow is beautifully apparent. Also the old river terraces are much more evident. The abandoned river channel that passes west of Hill 3220 is short enough and clear enough to be quite evident on the size map to which we are restricted by page size.

The springs in Box Canyon and in Blind Canyon may have been instrumental in producing the canyons by sapping the rock underlying the lava. The islands off the mouth of Falls Creek are sandbars, whereas those between the Flume and Kanaka Rapids are rocky. The Flume carries water from Banbury Springs to the swimming pool at Banbury Natatorium.

Exercise 8

Deltas

Deltas may take many forms, and the bird's-foot configuration is just one kind of delta. These are rather uncommon. Both arcuate and estuarine deltas are more common. A fine arcuate delta is found on the Detroit, Michigan, sheet of the 1:250,000 maps. It is the delta of the St. Clair River in Lake St. Clair, the smallest of the Great Lakes. We selected the Mississippi bird's-foot delta because the map shows every feature of a delta. A beautiful visual aid can be made by joining the entire Breton

Sound and New Orleans sheets. This will show in good detail the deltaic origin of southern Louisiana and that portion of the coastal plain. Photograph Exercise 10 shows a stereoscopic view of the Suwannee River delta.

Exercise 9

Sand Hills

The great sand-hill area of Nebraska extends into NE Colorado and NW Kansas. It is the result of desert conditions that existed in the region during the Pleistocene Epoch. Vegetation has now stabilized most of the huge sand dunes that were created. A plentiful supply of water is trapped in the sand and seeps out in the hollows between dunes. Other water is available from an aquifer that can be reached economically by drilling. These sources of water have played a large part in the development of the region as ranch land. The area we selected for the exercise is characteristic of the region. Photograph Exercises 16 and 17 show sand dunes in desert areas.

Exercise 10

Water Table in Limestone Country

This exercise can be used as a study of sinkholes. First approximation of the upper surface of the water table from the elevations noted for several of the lakes is that it dips southward and eastward. This impression is corrected in Part F, which shows that the water-table level is more complex than it first appears. Part F should be required of the more able students in the class. Photograph Exercies 3 and 4 will be helpful to use with this exercise.

There appears to be a broad east-west area in the northern part of the map where the water-table surface is above 120 feet a.s.l. There is another small east-west rise in the southern part of the map where the table also is at, or above, 120 feet a.s.l. The area between these and west of Lake Wales is high, but not quite 120 feet a.s.l. The lakes in this region have levels of between 120 and 115 feet a.s.l. The little lake south and just east of Mountain Lake has a level of between 135 and 130 feet a.s.l., suggesting a steep slope up from Mountain Lake.

Exercise 11

Ice Fields and Alpine Glaciers

We chose this map for this exercise because it shows in a compact area a great many alpine glaciers and a small ice field. The ice field is about 12 miles wide and over 25 miles long. The most clearly defined system of alpine glaciers is that of Johns Hopkins Glacier in the NW portion of the map. This is the basis for the study required to answer the questions in Part A. For a stereoscopic view of a glacier, see Photograph Exercise 6.

There is no doubt that during the Pleistocene Epoch the entire region was under a single ice field. Late- and post-Pleistocene melting has reduced much of the region to an intricate system of alpine glaciers that are frequently confluent at their heads. Interesting supplementary exercises can be constructed around this fact. Such exercises should be restricted to a relatively small area of the map. For example, a study could be

made of the confluence of the Johns Hopkins Glacier and the Lamplugh-Reid-Brady ice field. Other supplementary studies can be devised, such as a study of the changes in gradient of the surface of the ice throughout the length of a glacier.

Exercise 12

Alpine Glaciation

The Mount Evans region west of Denver, Colorado, is an excellent example of biscuit-board topography. Before glaciation these high mountains were gently rounded. Alpine glaciers have gouged huge cirques from their sides. With one exception, these cirques lie on the easterly sides of the mountains. There are several areas of unglaciated mountain that are sufficiently large to show the original form. See Photograph Exercise 13.

The moraines that contain the larger lakes in the eastern basins are low, and the 40-foot-contour interval does not show them well. The moraine that contains Summit Lake can be recognized on the map but is too vague to require any but the ablest students to find it. The map also shows indications of the moraine that contains upper Chicago Lake. Between the upper and lower lakes is a good example of a rock step. This must have been an area of great crevassing and serac when the glacier was active.

Additional profiles should be suggested to fast-working students. One running the length of the cirque containing the Chicago Lakes will clearly show the rock step. Another profile at right angles to this through the exit of upper Chicago Lake will show the U-shaped cross section of a glacial trough. Cross-section profiles well away from the headwall of any of the cirques will also demonstrate this feature. A profile from the summit of Mount Evans to the summit of Epaulet Mountains will demonstrate unglaciated slopes and a pass.

The four small lakes that are not labeled may or may not be moraine lakes. Only investigation on the ground would solve this question. Only three of the moraine lakes are so placed that there is evidence from the contours that they are such. Cautious students may mark only these as moraine lakes. They should not be penalized for their scientific caution.

Exercise 13

Continental Glaciation

We have used this U.S.G.S. quadrangle for the map of continental glacial forms because it represents the principal types of terrain associated with the borders of the retreating ice sheet. (Also see Exercise 28.) There is a little of almost everything except terminal moraine on the section we used. For a stereoscopic view of kames and an esker, see Photograph Exercise 14.

If you have the original full sheet at hand, you can point out to your class the evidence of an old glacial lake in the NW portion of the map. Groton Fairgrounds lies about in the center of the portion of the lake bed on this sheet. The kames and drumlins in the central and north-central portion of the sheet stand on kame terraces. Some of these are seen in the NW quarter of the exercise map.

Exercise 14

Drumlins

The drumlin swarm found in the area around Palmyra, N.Y., is probably the best example of this phenomenon in North America. These drumlins show all the characteristic features. The portion of the swarm shown on the map characterizes the entire swarm, which covers many times the area we show. Drumlins form near the melting edge of ice sheets, and until recently the mechanics of their formation have been an enigma. At first they were likened to sandbars in a river and were thought to be built around an obstruction.

Dissection of several drumlins for fill material proved this idea wrong. They are composed, in general, of a bouldery clay. Recent interest in clay minerals and the behavior of clay under a variety of conditions has helped us to understand drumlin formation. Clay has the capacity to absorb large quantities of water without becoming fluid. However, once the maximum amount of water has been absorbed, then a little added water converts the firm clay mass into slimy, slippery fluid. It is believed that accumulation of glacial clays in favored areas built up to great thickness. There, meltwater saturated parts of the clay mass, but not all of it. Where the thoroughly wet clay was exposed to more meltwater, it flowed away with the subglacial streams. This is believed to have left the less wet clay behind in the rounded, elongated hills that we call drumlins.

Exercise 15

Plateaus I

This portion of the Mogollon Plateau and Tonto Basin region is well forested. Editions of the U.S.G.S. sheet are available with or without a green overlay to indicate the forested areas. See Photograph Exercises 15 and 22.

The surface of the plateau is somewhat dissected by streams, but in general it is nearly level. The gradient of about 1.4 feet per 100 feet is a very slight one. The escarpment, on the other hand, is very steep, about 115 feet per 100 feet. This becomes a concave slope into the basin. Such a slope is quite characteristic of plateau escarpments. The upper parts of the Tonto Basin are quite rugged and contrasts markedly with the plateau surface.

Notice that the consequent streams on the plateau form an essentially parallel pattern, whereas the obsequent streams of the escarpment are dendritic. The spring line in the face of the escarpment is an important source of water in this region. It may be represented on the plateau some distance to the north of the area on the map. There is a spring line on the mapped area, at about 7500 to 7600 feet, that lies in a higher stratum in the column.

Actual stream-gradient assignments should be made to the more able students in your class. From Tonto Spring to Kohl Ranch, the gradient of Tonto Creek averages about 5 feet per 100 feet (1150/227). Beaver Creek, running down Beaver Canyon on the plateau from its source to the junction with Turkey

Creek, averages about 2.5 feet per 100 feet (700/286). Another good supplementary assignment is the preparation of a profile across the rim, say in T12N,R12E from the corner of section 23 and 27 to the corner of section 33 and section 5 in the township below.

Exercise 16

Canyons

The Grand Canyon is such a vast structure that it cannot adequately be studied from a single topographic sheet. We have selected a portion of the Bright Angel sheet that shows many of the salient features of the canyon. The consensus of geologists who have studied the region is that during the Pleistocene Epoch, the Colorado River cut its way through the column of sedimentary rocks and into the Vishnu formation beneath. This limits the time of major canyon-forming activity to a million or two million years.

Much of the sediment eroded from the canyon country was carried by the Colorado River to the Gulf of Lower California. Here, it was deposited as a dam across the head of the gulf, causing the Imperial Valley to form in California. Therefore, this area that was once the floor of the gulf is now below sea level.

For stereoscopic views of canyons, see Photograph Exercises 22 and 23. A recent, very fine, and well–illustrated description of the Grand Canyon can be found in Chapter 21 of *Geology Illustrated*, by John S. Shelton, published in 1966 by W. H. Freeman Co.

Exercise 17

Plateaus II

There are many other areas in the Ozark Plateau that can be used for exercises similar to this. There are also excellent areas in western West Virginia that lend themselves to the study of maturely dissected plateaus. The U.S.G.S. special topographic sheet for Glacier National Park, Montana, is also a striking one. It shows a maturely dissected plateau terrain with a stream system much "coarser" than the one on the sheet we have used, and the remnants standing impressively high above the valleys. Most of the valleys are U-shaped from alpine glaciation. See Photograph Exercises 3 and 21.

Exercise 18

Drainage Patterns

Mount Monadnock has given its name to the physiographic feature that it is, namely, an isolated mountain peak. Such isolated mountains are often the result of peneplanation that has reduced the surrounding country to a common low level. These mountains usually share a radial drainage pattern with dome mountains, but they lack the surrounding series of hogbacks, or upturned sedimentary rocks, associated with domes. See Photograph Exercise 27.

Mount Monadnock is surrounded by areas covered with glacial till. The mountain itself has slopes that were steepened by the movement of ice that surrounded it. Part of the time

during the last glaciation, ice did not override the mountain but left it an island, or nunatak, rising above the level of the ice sheet.

Although there are many glacial features of topography shown on the section of the full U.S.G.S. sheet that we used, we have not emphasized them in the exercise. Other exercise maps show the same features in more easily recognized delineation. You will find an excellent description of the geology of the entire quadrangle in *Journal of Geological Education*, 15:191–192, December 1967. A longer article was published by the State Planning and Development Commission, Concord, N.H., in 1949.

Exercise 19

Folded Mountains

Attempts to recognize eroded anticlines and synclines from topographic maps are often unsuccessful. Therefore, in this exercise we have described the structure from field information. The relative hardness of the rocks can be estimated roughly from the degree to which they are cut by streams, and from the roundness of the residual forms. The more dissected ridges and those with the rounded forms are usually composed of easily eroded sedimentary rock. See Photograph Exercises 25 and 26.

Fort Valley in the central part of the map is a broad synclinal valley. Little Fort Valley is subsidiary, and is a strike valley in the strata that form the flank of the syncline. The uneven crestlines of the ridges suggest that considerable erosion has taken place since peneplanation.

The stream pattern in Little Fort Valley is quite characteristic of the folded portion of the Appalachians. Stream captures of the type suggested here can be found on almost any topographic sheet of the region. The original outlet from the valley was probably through Mine Gap, since that leads from the lowest part of the valley. A capture through Woodstock Gap diverted the SW tributary. A stream through Duncan Gap probably beheaded the NE part of the system only to be beheaded later itself by a stream from the southeast through Mudhole Gap. For a stereoscopic view of stream capture, see Photograph Exercise 9.

The wind gaps, Boyer and the unnamed one between it and Mine Gap, may represent the remains of early captures that in time were unsuccessful. Trying to guess the past is interesting, but in general the conclusions are only educated guesses.

The North Branch of the Shenandoah River is an ideal entrenched meandering stream (see Photograph Exercise 8). The cutbanks and slipoffs are clearly defined by the contours. The direction of flow can be discovered from the contour lines that cross the stream. The attack upon the NE banks is aided by the Coriolis effect. The dark-blue bars across the stream, especially noticeable on the South Branch, indicate rapids.

Exercise 20
Faults

It is difficult to find good examples of faulting that can be recognized by beginners in the art of map reading and interpretation. Stereoscopic views of the effects of faulting may be seen in Photograph Exercises 23 and 24. Strike-slip faults, such as the well-known San Andreas Fault system, are inconspicuous on maps of the scale 1:24,000. The displacement is so little that the stream offsets by which the fault may be recognized are of the order of 0.01 inch on the map. Dip-slip faults are more easily recognized, provided the contour interval is small enough. The striking series of faults that are shown on this map continue into adjacent areas north and south of the Jellico sheet. Likewise, the Klamath Lake area of Oregon contains faults that can be easily recognized on maps.

On this map there is a fault that is not mentioned because it is not so well defined as the one upon which the exercise is based. This fault produced Butte Creek Rim, which parallels the eastern margin in the north half of the sheet. It may be related to the volcanism that produced Bald Mountain, a cone that is older than Cinder Butte. In addition to the profile that is required for Part B, others may be suggested to students who work rapidly and accurately. We recommend using the east-west section lines between sections 17 and 20 in T35N; between section 32, T35N, and section 5, T34N; between sections 22 and 27, T34N; and between section 34, T34N, and section 3, T:33N. These four in addition to the one required will produce a clear picture of the fault zone.

Exercise 21
Fault Block Mountains

It might be well to follow this exercise immediately with Exercise 20, which includes a study of recent splinter faults.

Fault block mountain ranges abound in the West, but few topographic sheets clearly show the features that are used to recognize such mountains. The best of these are from the great series of escarpments along the western front of the Wasatch Range in Utah. The section we have used presents in rather easily recognizable form the position of the fault and the coalescing alluvial fans. In this case the fans extend into the adjacent lowland, the Juab Valley. All this exercise is based on overlays on which the pupil locates certain features.

To the north of the region there is evidence that movement along these faults has not stopped. In the vicinity of Provo and Salt Lake City a number of glacial moraines that extend westward a little from the mouths of canyons are crossed by recent faults, and the morainal and alluvial material is displaced from 15 to 30 feet.

Your students should have little difficulty discovering the four segments of the main fault. Actually they will be locating the fault scarp. The fault itself lies buried in alluvial outwash. The areas of confused topography where there are offsets of the faults are also easily located.

The alluvial fans are also easy to see. Those produced by Birch Creek, Willow Creek, and Couch Creek should be properly identified with those names. The two fans to the north of the Couch Creek fan were formed by the creek in Bear Canyon and by Mona Creek. Now both of these streams are diverted to the shallow valleys south of the fans they built. These valleys are filling with alluvial detritus. This is the way the piedmont slope is formed from coalescing fans. North Creek has slipped off the northern side of its fan, and Mendenhall Creek off the southern side of its fan. The stream in Wash Canyon now flows north of its fan.

Triangular facets are often very obscure on topographic sheets. The one we have pointed out in Part B is about as good as you will find. Erosion has so channeled the face of most facets that they are hidden in the details of the contouring. Usually the apex of each facet is the point where a ridge, running more or less at right angles to the main ridge of the mountains, branches and forms two ridges that diverge as they drop to the level of the lowland. A stream frequently exits from the mountains at these two points.

Exercise 22

Domes

The limiting factors of this book have made it difficult to find good representation of entire dome mountains on maps. We wanted a dome that clearly shows radial and annular drainage, hogbacks, and flatirons. We found two topographic sheets that depicted interesting small domes: Sundance and Inyankara Mountain quadrangles in Wyoming. Neither is perfect for our purposes. Combined they are excellent. With space for only one map we settled upon the Sundance quadrangle. Little Dome, Wyoming, is shown in Photograph Exercise 27.

There are many other quadrangles from western states that exhibit such features as hogbacks and flatirons on domes much too large to be shown on a single sheet. Excellent hogback structures are found on the Morrison, Colorado, quadrangle. Fine flatirons are to be seen on the Boulder, Colorado, quadrangle. The Fort Meade, South Dakota, sheet shows a fine dome, Bear Butte, but the contours are so close together that the principal features are obscured in the details. The Maverick Springs, Wyoming, sheet is fine for all dome features but must be used in its entirety.

Exercise 23

Volcanics I

This map of the Menan Buttes, taken from the larger U.S.G.S. quadrangle of the same name, contains, in addition to the volcanic features, several good river features. Along the Henrys Fork of the Snake River there are good meanders, a cutoff, meander ridges, and several floodplain stream captures. There are also man-made levees and an irrigation canal. You can construct a good map exercise for meandering streams, based on this map.

The two volcanoes are more cinder cone than any other specific type. There are, however, some evidences of lava flows in the cones. The cones represent a second generation of eruptions on the same fault. Just a portion of the older volcano is evident, a rim from the western to the NE side of the original cone. Northwest of Menan Buttes there are extensive lava flows, and northeast of the north cone there is evidence of some lava that flowed from the cone. River action has cut away some of the slope of the south cone from the NE foot to the SW edge.

The shaded edition of the map shows the forms of the land, but on the cones it obscures the contouring. A copy of the full-sized shaded sheet (Menan Buttes, Idaho, 1:24,000 shaded relief edition) can be procured from the U.S.G.S. and would be a useful adjunct to this exercise.

Exercise 24

Volcanics II

This exercise should follow Map Exercise 23. It can be used at the same session for your quicker students while the slower ones are completing Exercise 23. Or it can be used as a test of the student's ability to interpret maps and draw conclusions from them. Photograph Exercise 28 is a fine stereoscopic aerial view of the same area as the map.

Exercise 25

Shorelines I

By far the best maps to use for the study of shorelines are the U.S.G.S. topographic sheets in the 1:250,000-scale series. The larger-scale maps, 1:62,500 and 1:24,000 series, are excellent for the detailed features found along shorelines, but they rarely show enough area on a single sheet to allow generalizations to be formed. Sheets of the 1:250,000 series are available for the entire coasts of the United States, including Alaska and Hawaii. Photograph Exercises 18 and 19 are stereoscopic views of shorelines.

We selected this particular sheet because it clearly shows the effect of the rise of sea level in post-Wisconsin time. The stream valleys that had been cut into the low coastal plain during the glacial period of low sea level have been invaded by the rising water, and each stream has become an estuary. The action of waves and currents has built long barrier bars offshore that in the region shown on our map carry the local name of *bank*. The depth lines, at 5-fathom intervals on this sheet, were taken from hydrographic charts, and the depths were converted into feet.

The submerged spit extending southward from Cape Lookout is covered by very shallow water, and at extreme low tide, areas on it are almost awash. Winter storms have earned for the coast from Cape Hatteras south to Cape Lookout the title "graveyard of ships." It was a most fitting title in the days of sail, and continues to be so.

Exercise 26

Shorelines II

The coast of Texas is a long series of barrier beaches and islands, from the mouth of the Rio Grande to the Louisiana border. A

very fine visual aid can be made by putting together the sheets from the 1:250,000 series of maps published by the U.S.G.S. Few classrooms have sufficient free wall space to assemble these. Any three contiguous maps will be impressive and most useful while you are discussing emergent coastlines. We studied all these maps before settling upon a section that was varied enough to include most of the features associated with the development of an emergent coastline. See Photograph Exercises 18 and 19.

Eastern Texas is a broad coastal plain that started emerging from the sea in the Late Cretaceous or Early Tertiary. Emergence probably is continuing at a slow rate. Wave action and longshore currents have built unusually long barrier bars and beaches across the slightly irregular shoreline of the mainland. These have developed quite a way offshore because of the gentle slope of the continental shelf in this region. The lagoons behind the barriers are filling with sediments poured into them by runoff. One of the features that helped us decide on the map we used is that it shows a lagoon still open to the sea and another that is closed off.

Exercise 27

Shorelines III

This is an opportunity to tie earth science together with the history of early exploration of North America. You might have one of the students do research in your library and present a report about Sir Francis Drake, as a supplement to this exercise.

The full-sized U.S.G.S. sheet from which our map was taken shows all of Tomales Bay, which is also shown in Photograph Exercise 18. It might be mentioned that the map area is just west of the great San Andreas Fault zone. Since the middle of the Tertiary Period, land to the west of the bay may have moved north along the fault for more than 200 miles. The movement along this fault may be as much as 20 feet per century.

The map we present shows good examples of the stages by which an irregular submerged coastline is smoothed into a uniform one. The ocean shoreline has been smoothed, and the only evidence of its former irregularity is Abbotts Lagoon. The estuaries entering Drakes Bay are being closed off by sand that is carried by longshore currents and refracting waves. They are also being filled by sedimentation at the bayheads. The marsh in Drakes Beach County Park is an almost extinct baylet; the closed lagoon east of the D Ranch is the previous stage.

Exercise 28

Shorelines IV

A study of shorelines can be undertaken *before* considering continental glaciation by using this exercise and omitting Part A. This exercise can also be used for testing purposes after the study of continental glaciation.

The portion of the map that we have used clearly illustrates the characteristics of an outwash plain, of stadial moraine, and of a beach along a submerged coast. The shaded edition of the

full map is beautiful, and a copy should be on hand for the students to see. It is one of the maps in the set of 100 sold by the U.S.G.S. A synopsis of the geology of this sheet will be found in *Journal of Geological Education*, 15:193–194, December 1967.

The region north of the Post Road is largely morainal and contains a kame terrace. There are some sinuous, linear hills in this area that have some features of eskers. (See Photograph Exercise 14.) A good example of one of these lies to the east of the road leading northward from Perryville. The region south of the Post Road is a characteristically pitted outwash plain. Green Hill and the hill on which the triangulation station, Weeden, is situated are drumlins or drumlinoid hills.

Where it is not rocky, the shoreline shows many features of a submerged coast. Bay-mouth bars have formed across the embayed lowlands of the outwash plain. These have been built up to 10 or more feet a.s.l. On Browning Beach one point reaches at least 20 feet a.s.l. Tidal currents, rather than river-induced currents, maintain open communication between the sea and the lagoons, called ponds on the map.

Exercise 29

Coastal Details

Long Island, N.Y., is built of continental glacial moraine and outwash. The moraine disappears beneath the sea at the eastern end of the island. Farther east it emerges, and Block Island, R.I., and Nantucket Island, Mass., are also parts of this moraine. Still further east, extending to Nova Scotia, the moraine is under the sea and forms the famous banks of the Gulf of Maine.

There is evidence that during glacial times the shore in the Long Island region may have been as much as 100 miles farther out to sea than it is today. As the glaciers melted, the water that was returned to the sea raised sea level over 300 feet. This flooded much of the area covered by glacial outwash, and the sea invaded the moraines. The two most prominent moraines form the long spurs of Long Island, which extend eastward at the eastern end of the island. Gardiners Island, Shelter Island, and several smaller islands lie in the flooded land between the two major moraines.

Early maps of the region show the three islands now tied to Shelter Island as true islands. The necks creating the tombolo noted in the exercise have been built during the past 200 years. Evidence of the effect of the longshore current can be seen in the cliffs that have formed at the NW corner of Little Ram Island and the NE corner of Ram Island. The angle at Nichols Point is too acute to have been formed by other than two opposed currents.

Exercise 30

Submergent Coasts

The coast of Maine is a beautiful example of a recently submergent coast. In some places it approaches a typical fjord coast. The section of the coast that we selected to use for this exercise exhibits the majority of features of a young submergent

coast. If this exercise is used after the study of an emergent coast (Exercise 26), Part D should be answered by your pupils. However, if you choose to use this exercise before Exercise 26, Part D should be delayed until Exercise 26 is completed.

It will be instructive to your pupils to exhibit Sheet 3 of the U.S.G.S. *Map showing relation of land and submarine topography*, Nova Scotia to Florida, (Misc. Geol. Investigations, Map I-451, 3 sheets, 1965). This map will show you that the ice sheets once extended seaward to the outer edge of the banks.

Teacher's Guide for STEREOSCOPIC AERIAL PHOTOGRAPHS FOR EARTH SCIENCE

Aerial photographs were first used for geographic purposes in the 1890's. The county surveyor of Staten Island, New York, suspended a camera from a balloon and towed the balloon around. The photographs that were produced were fitted together to make a mosaic of the island. The next landmark was in World War I, when cumbersome plate cameras and later film cameras were carried by aircraft to photograph enemy positions. Sherman Fairchild realized the peacetime potential of these early aerial cameras and spent a fortune developing precision mapping cameras.

By the middle of the 1930's the U.S. Geological Survey began to use aerial photographs as the basis for topographic maps. Today almost all mapping is done from the air. The photographs used in this book were taken for such a purpose. These photographs overlap one another by about two thirds. This overlap allows you to study the images in three dimensions.

Because successive photographs are taken from different points along the course of the airplane, there is parallax in the images of identical terrain features in successive photographs. It is this parallax that allows you to see the terrain in three dimensions. This sort of photography exaggerates the principle upon which your eyes operate.

You see in three dimensions because each eye sees a slightly different view of the same object. Your eyes see views from points that are 2 to 2½ inches apart—the distance between the centers of the pupils of your eyes. Such a short stereobase allows you to perceive three dimensions only in objects closer than 500 feet.

The aerial photographs used to produce stereograms have stereobases that are thousands of feet long. This causes the relief to be exaggerated and to be very evident even when the photographs were taken from more than 30,000 feet above the terrain. This means that buildings, trees, or hills are not so high as they appear in the 3-D image you see through the stereoscope. This is bothersome at first. In a short time, usually during the first session in the laboratory, you will learn to ignore the vertical exaggeration. The exaggerated vertical dimension is helpful in studying the details of structures. Shadows are also useful in studying details.

The pocket stereoscope is a simple device that isolates and slightly enlarges the image for each eye. Sections of the two photographs are fused in the brain where a 3-D impression is formed. The first attempt to achieve 3-D vision with a stereoscope may be difficult. Encourage your pupils to look up frequently from the stereoscope until their eyes are relaxed.

Some people develop the ability to look at a stereogram without a stereoscope and to see a 3-D image. Others never see one even when using the best of stereoscopes. These are people with faulty vision, often with one eye so dominant that the other fails to see. If a person wears glasses, he should use them when first looking through a stereoscope.

Using a stereoscope and properly aligned stereograms can have no harmful effects. In fact, exercises similar to these are used by doctors to strengthen eye muscles. At first, the unaccustomed exercise may cause a mild headache. Therefore, the early laboratory periods devoted to the use of stereoscopic viewing should be restricted to not more than 30 minutes. After two or three exercises there need be no limit to the time. For psychological reasons, it is best not to mention potential headaches to the class!

Occasionally a stereogram is composed of photographs of terrain with extreme relief, such as those of Mount Sopris in Exercise 6. No one can be expected to bring into register in the brain the entire field of vision in such a case. If by the time you reach this exercise some of your pupils have not learned to concentrate their attention on a small area, suggest that they do so. It may be necessary for some pupils to look up between shifts from one area to another. Once they learn to pinpoint their looking at stereograms, they will have no trouble.

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Laboratory Investigations in

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